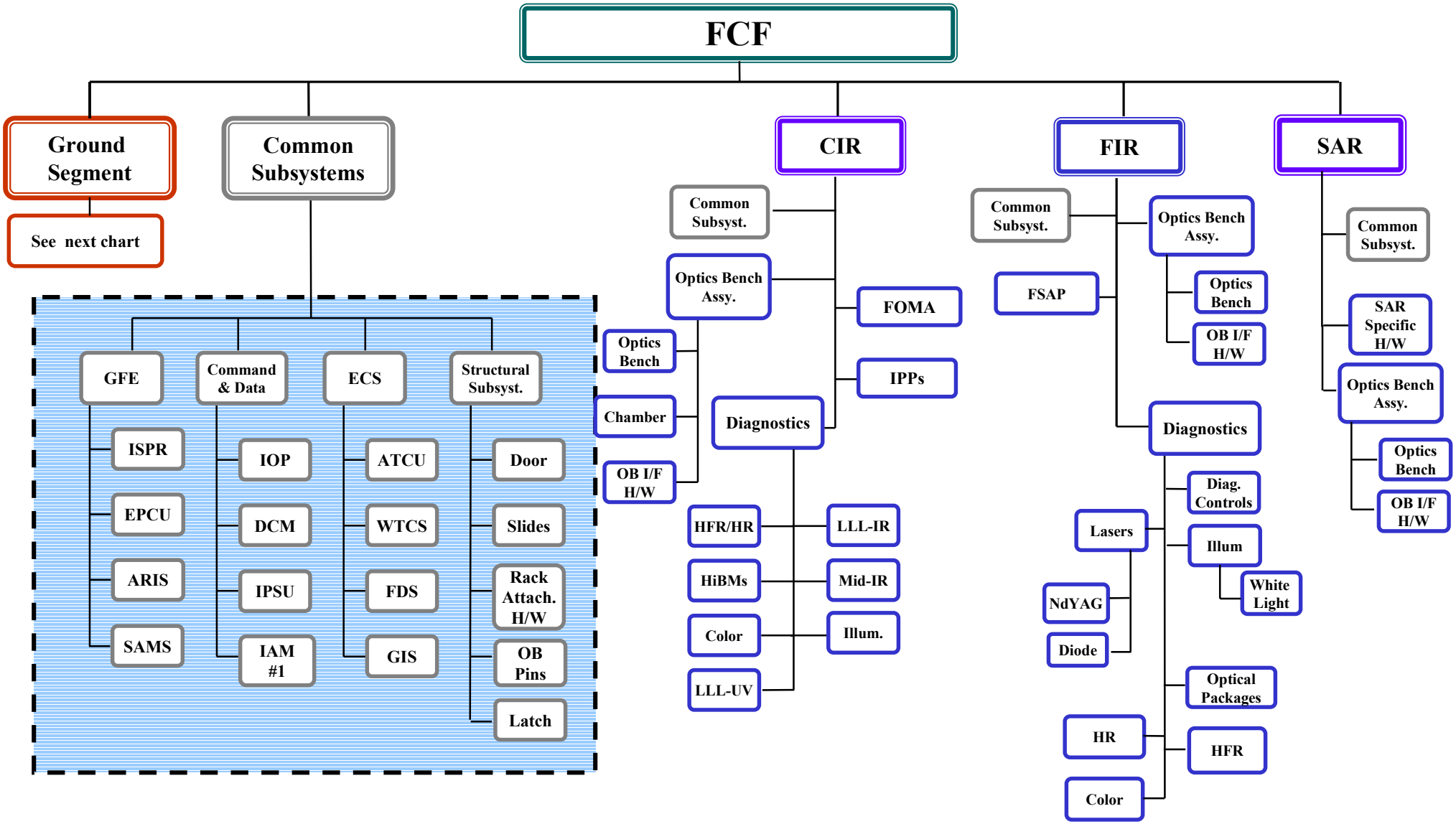
Common Hardware Description

Terri Rodgers & Nora Bozzolo

February 13, 2001

Fluids and Combustion Facility (FCF) System



Government Furnished Equipment (GFE)

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GRC

Government Furnished Equipment (GFE) Hardware

ISS Common Hardware (50K and 10K contract)

- ISPRs
- ARIS
- RMSA
- Shipping Containers
- Electrical/fluid connectors, fittings, etc.
- HRDL boards
- CVIT boards
- Smoke Detectors
- Rack Handling Adapters

GRC Contract Developed Items

- EPCU – Electrical Power Control Unit
- WFCA – Water Flow Control Assembly
- SAMS – Space Acceleration Measurement System

Space Acceleration Measurement System (SAMS) Triaxial Sensor Head (TSH)

- Measures general vibratory environment
- 3 orthogonal pendulous mass force-balance accelerometers in each TSH head
- Selectable bandwidth
- Digital data output and control through standard RS-422 serial interface
- Data sent to SAMS Interim Control Unit (ICU) over the ISS Ethernet
- ICU down links data to Principal Investigator's Microgravity Services (PIMS) for data analysis and distribution

Volume: 2.9" x 2.9" x 2.8"

Weight: ~1.1 lbs

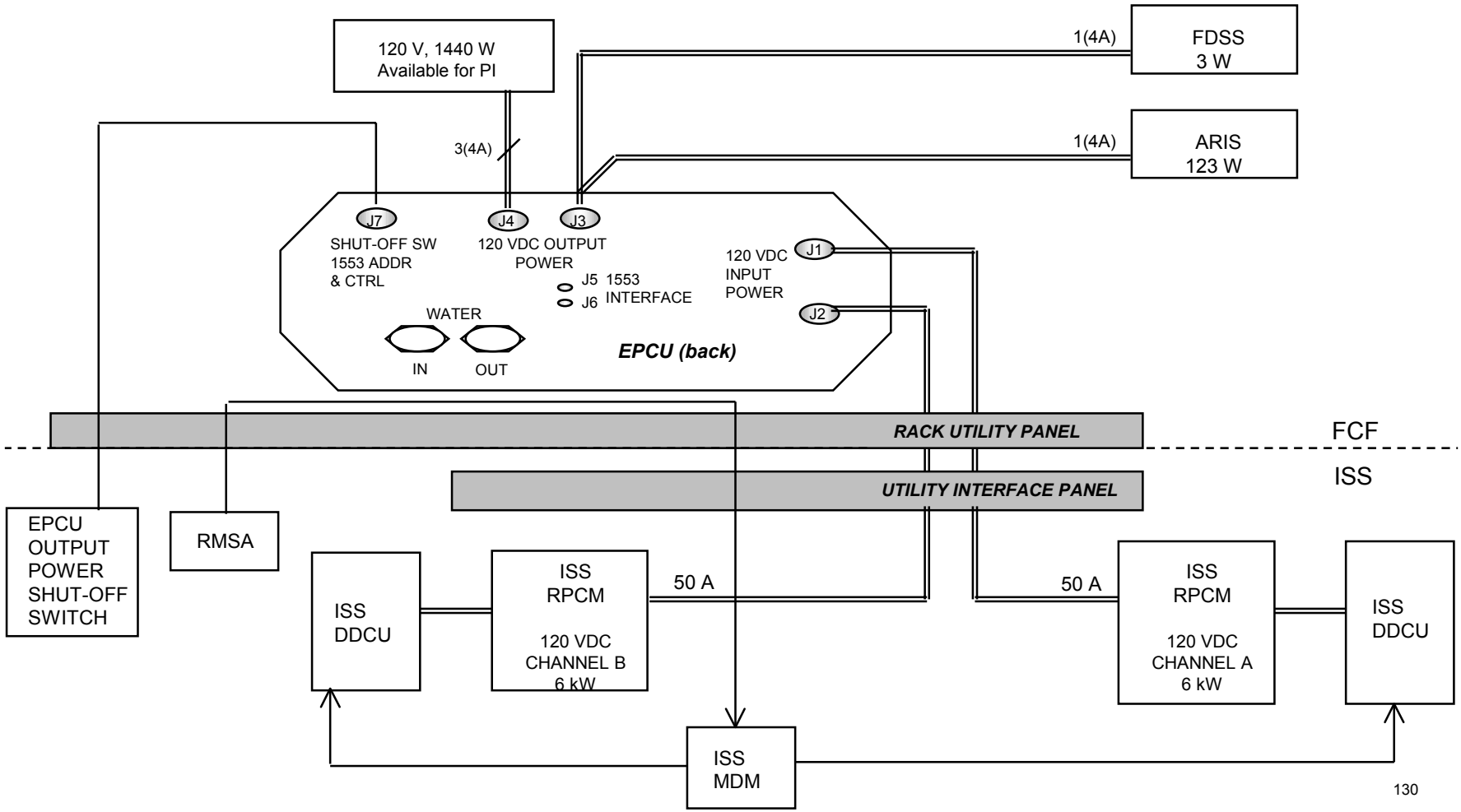
Power: +/- 15 VDC, 1.65 W

Electrical Power Control Unit (EPCU)

Electrical Power Control Unit (EPCU) Functions

- Power distribution
- Power conversion
  - 3 kW of 120 VDC to 28 VDC bulk power conversion
- Power control and management
  - All power output circuits are configurable by the user to allow for custom load configurations
  - Coordinated prioritized load shedding of all power output circuit
  - Power bus transfer capability for all loads
- Fault protection
  - 2.9 kW of unprocessed but protected power at 120 VDC
  - 6 fault protected power circuits of 120 VDC
  - 48 fault protected power circuits of 28 VDC

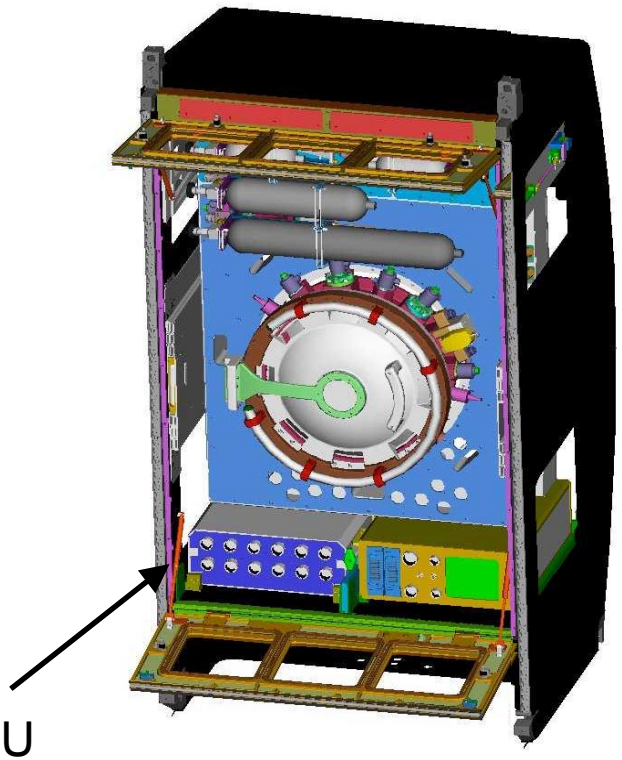
FCF Electrical System: 120 VDC Power Distribution



Electrical Power Control Unit (EPCU)

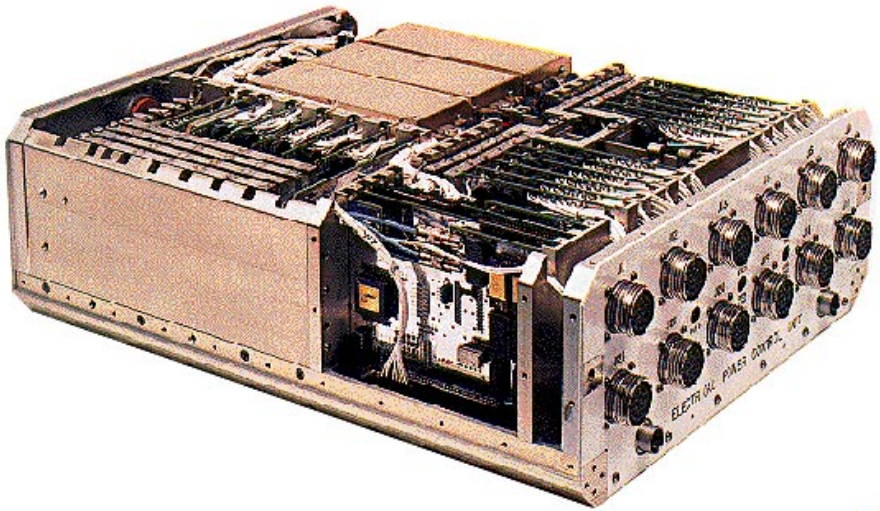
Hamilton Sundstrand delivered an engineering model of the EPCU to GRC in Nov. 1997

- Tested with high fidelity breadboards of the ISS electrical power sub system
- Tested with DCE preliminary hardware
- Testing performed
  - EPCU efficiency with no 120 VDC Loads
    - 89% @ 3 kW
    - 88.5% @ 1.5 kW
    - 83% @ 600 W
  - EPCU Efficiency with 120 VDC Loads
    - 95% @ 6 kW
    - 95.7% @ 3 kW
    - 94.4% @1 kW
  - Input impedance
  - Stand alone stability
  - Large signal stability
  - Common Mode Noise
  - Vibration Tests
  - Electromagnetic Interference (EMI)

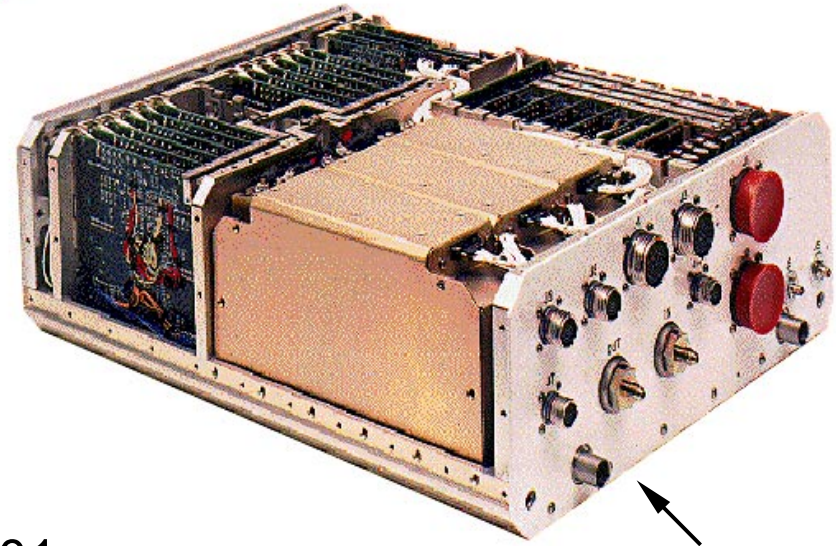


EPCU Location in Rack

Electrical Power Control Unit (EPCU)



Front Panel



Back Panel

Qualification Unit

- Currently being assembled
- Qual testing to begin March 2001

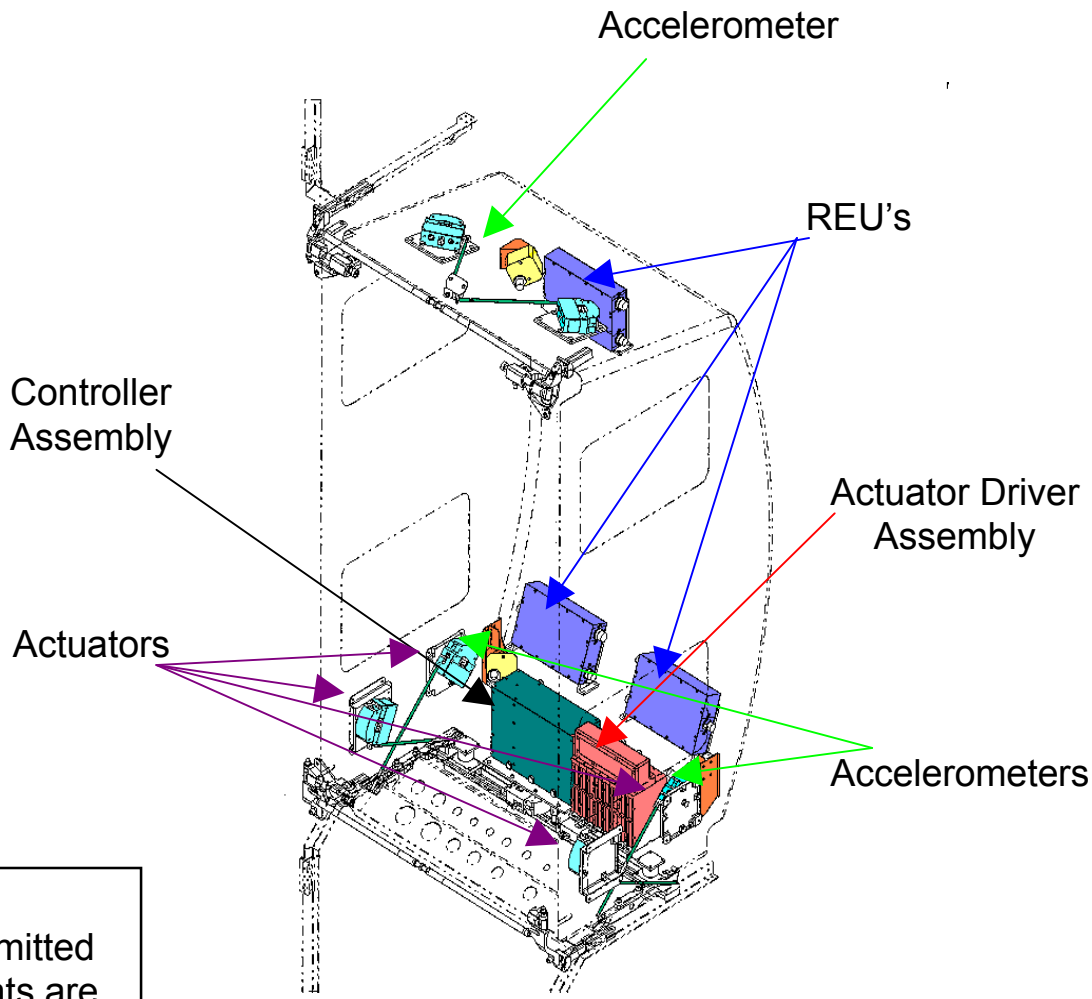
Engineering Model (EM) Unit

- To be tested at Space Power Electronics Lab (SPEL) in March 2001

Active Rack Isolation System (ARIS)

Major ARIS Components

- Remote Electronics Unit (REU)
- Accelerometer heads (3)
- Actuators (8)
- Controller and Power Supply
- Actuator Driver Assembly



ARIS provides rack-level attenuation of on-orbit low frequency/low amplitude mechanical vibrations transmitted from the US Lab to the rack when science experiments are conducted. ARIS is FCF's baseline approach for vibration isolation to meet acceleration requirements for fluids physics & combustion experiments performed in ISS.

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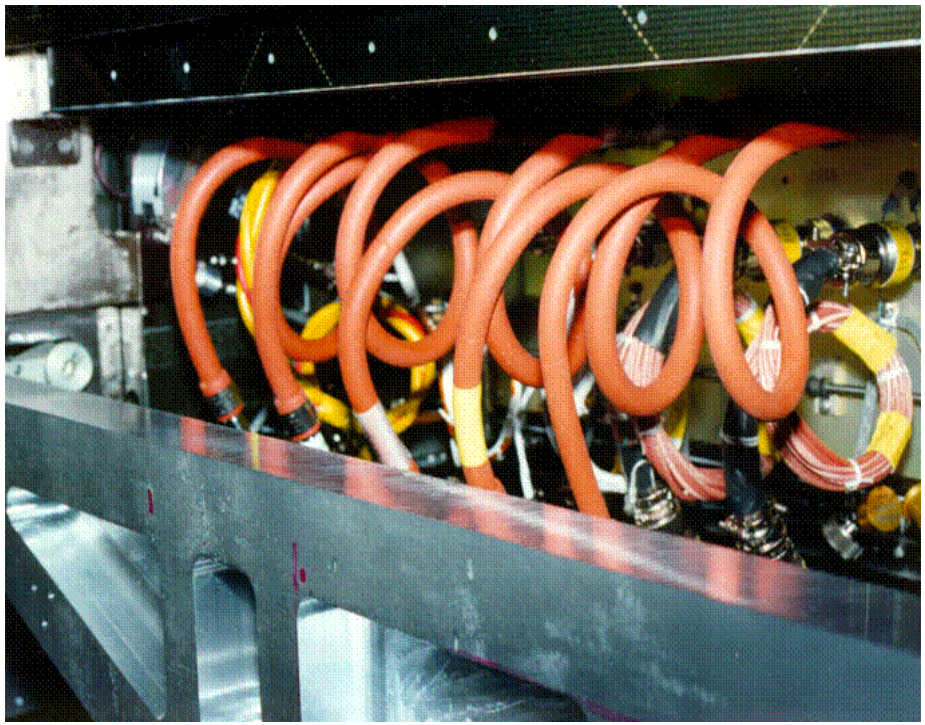
ARIS Modifications to Support FCF

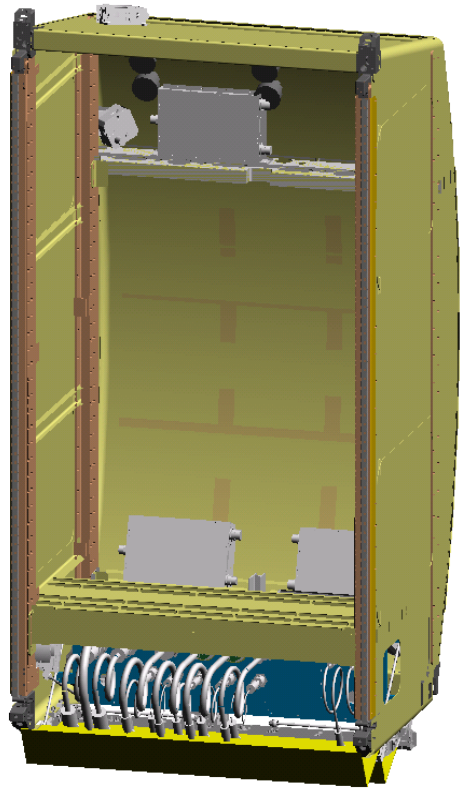
CR3272 Modifications and Analysis

- Cable rerouting
- Additional connector locations added to Rack Utility Panel (RUP)
  - rack-to-rack cabling
  - Rack Maintenance Switch Assembly (RMSA)
  - EPCU Shutoff Switch Assembly (ESSA)
  - laptop connection
- Assess impact of additional umbilicals on microgravity environment



ARIS Roles and Responsibilities

- Active Rack Isolation System (ARIS) Roles and Responsibilities for ISSP and FCF were added to the FCF PIA
- Program responsibilities
  - ARIS upgrades and International Standard Payload Rack (ISPR) modifications to accept ARIS kit
  - ARIS integration support
  - Technical support during rack build up
  - Systems test support
  - ARIS system sustaining engineering
  - Support for operations and training
  - Account for resources including ARIS weight and volume for components installed on-orbit; crew time for on-obit installation, stowage for on-orbit pre-positioned ARIS spare parts
- FCF responsibilities
  - Define integrated payload facility procedures.
  - Conduct ARIS system to facility systems testing
  - Account for ISS resources for payload specific ARIS requirements



ARIS Integration Task

Task initiated with ZIN Technologies to provide ARIS integration support.

Elements of the task include:

- Generation of an implementation support for an ARIS FCF specific Interface Definition Document (IDD) and ICADs to support each FCF rack. The IDD would document ARIS FCF common hardware interfaces. The ICADs would define all unique interfaces due to configuration differences between the racks (i.e. mass, umbilical layout, operational differences, etc.).
- Assessment of ARIS performance for center of gravity (CG) location per FCF rack.
- Providing science impact assessment due to ARIS operations parameters (transients).
- Tracking the development of ARIS ICE and interpreting results for FCF.

Ground Furnished Equipment (GFE) Issues/Risks

ARIS

- Receipt of PIDS compatible ARIS kit.
- Early receipt of ARIS FEU Controller/simulator to support software development.
- State change transients.
- RS232/1553 controller connection.
- Sway space due to venting.

Other GFE

- High Rate Data Link (HRDL) software and documentation support. FCF is pursuing the development of an alternative card to mitigate this risk.
- Receipt of Common Video Interface Unit (CVIU).
- Station Support Computers (SSC) and access to SSC cables for power supply characterization. Early receipt of ARIS FEU.

Common Subsystems

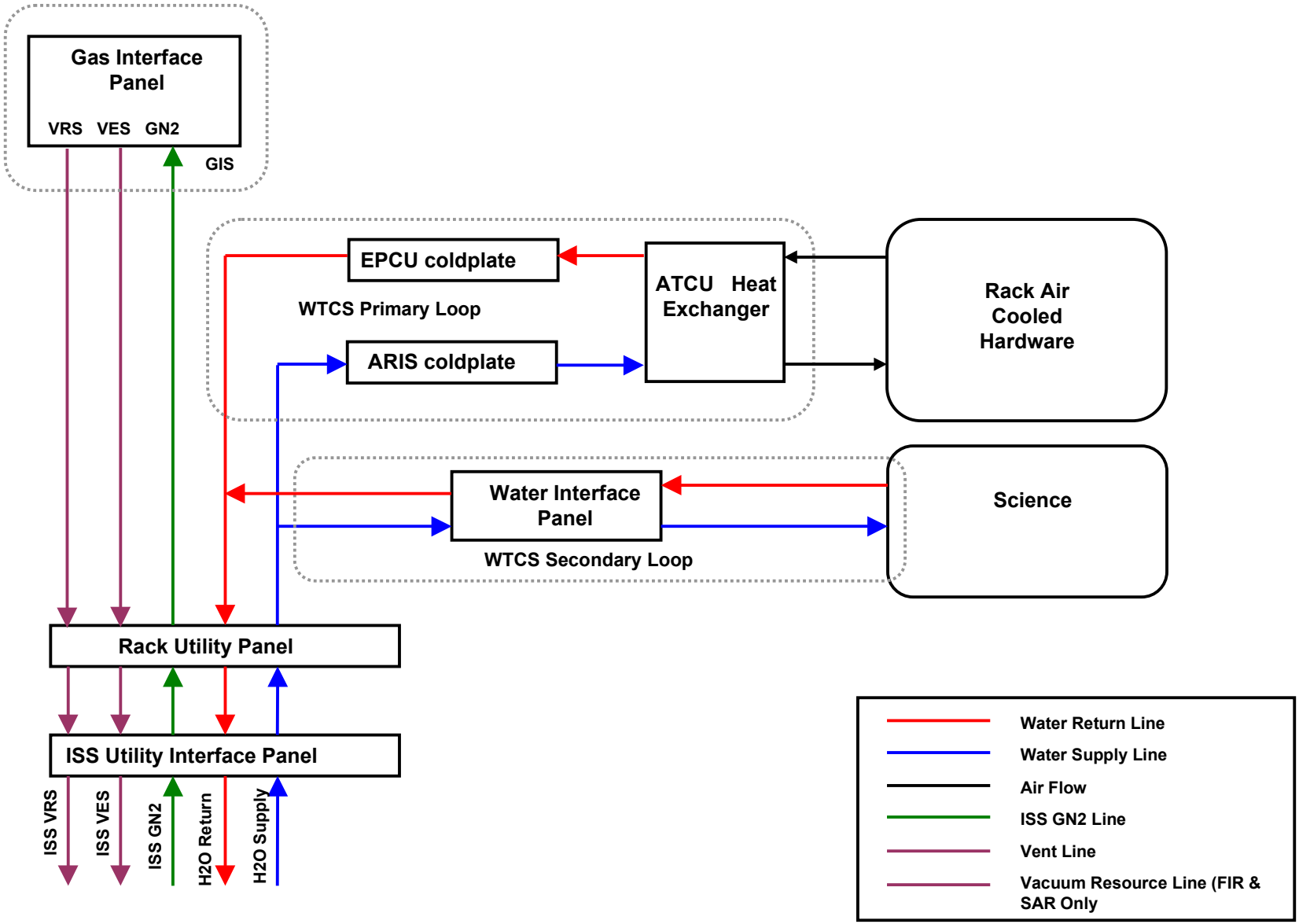
Nora Bozzolo
Analex

Environmental Control System (ECS)

Components

- Air Thermal Control Unit (ATCU)
- Water Thermal Control System (WTCS)
- Gas Interface System (GIS)
  - Gaseous Nitrogen (GN2)
  - Vacuum Exhaust (VES)
  - Vacuum Resource (VRS)
- Fire Detection and Suppression System (FDSS)
- ECS Electronic Unit (EEU)

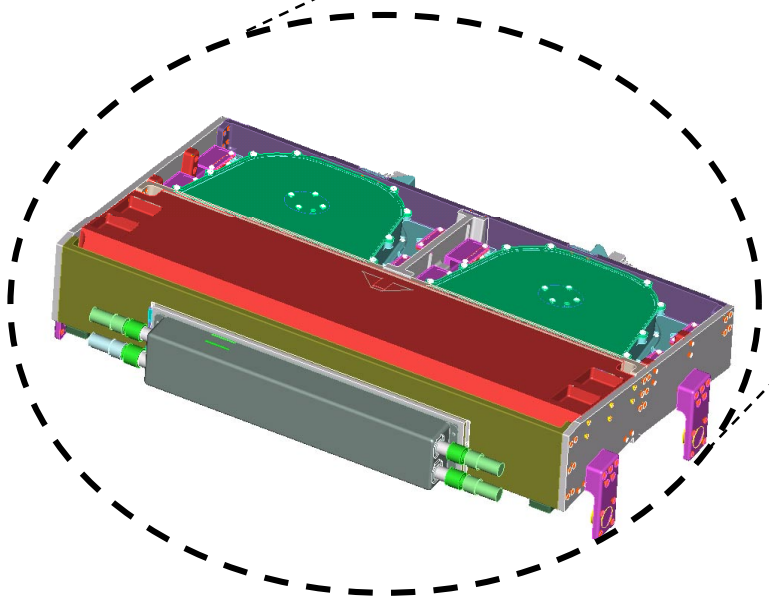
Environmental Control System (ECS) Block Diagram

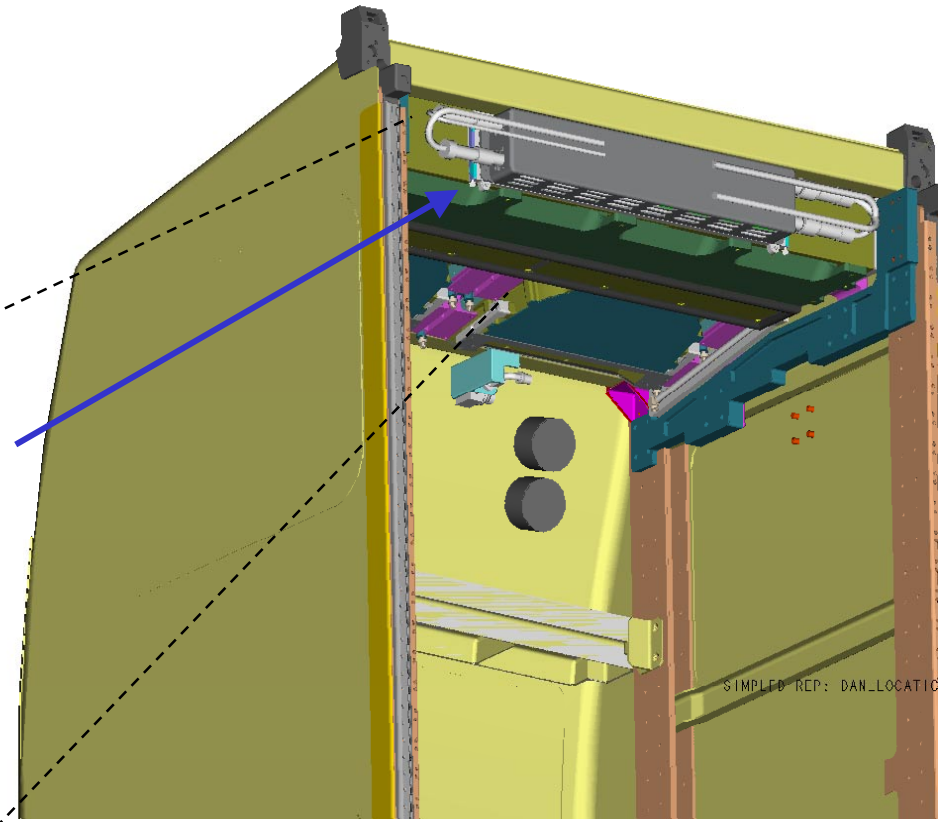


Air Thermal Control Unit (ATCU) Assembly

Function

- The Air Thermal Control Unit (ATCU) removes waste thermal energy from the rack's internal atmosphere.



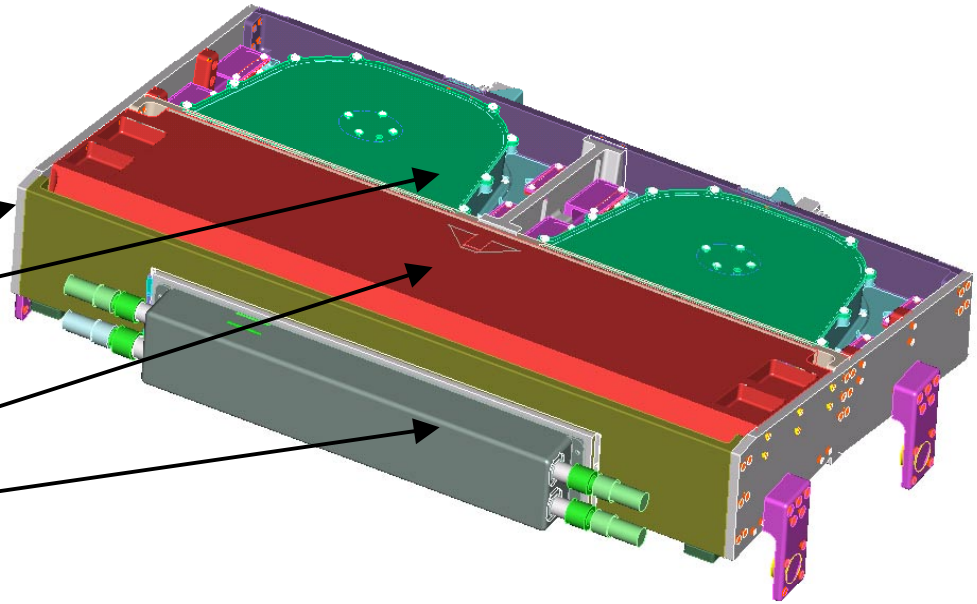


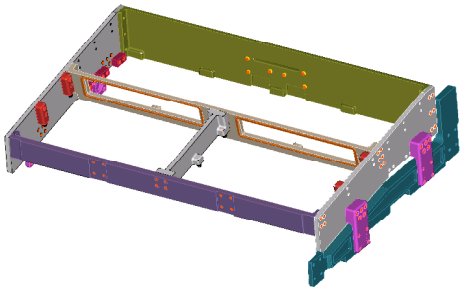
Design Goal

- Reject 1650 watts of heat maintaining avionics air inlet temperature below 30°C (86°F).

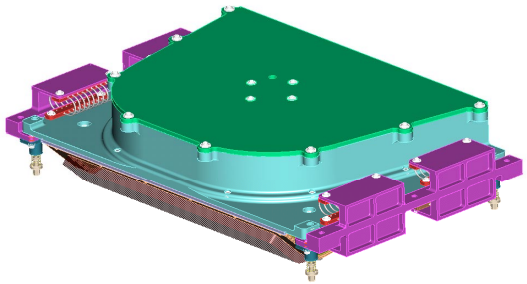
ATCU Components

- Air Thermal Control Unit (ATCU) Hardware Assembly
  - Frame Sub-Assembly
  - Fan Sub-Assembly
  - Heat Exchanger Sub-Assembly
- ECS Electronic Unit (EEU)
- ATCU Software

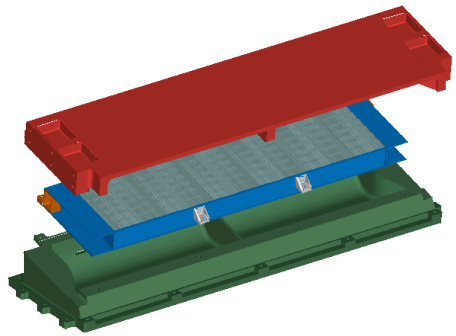




Frame Sub-Assembly



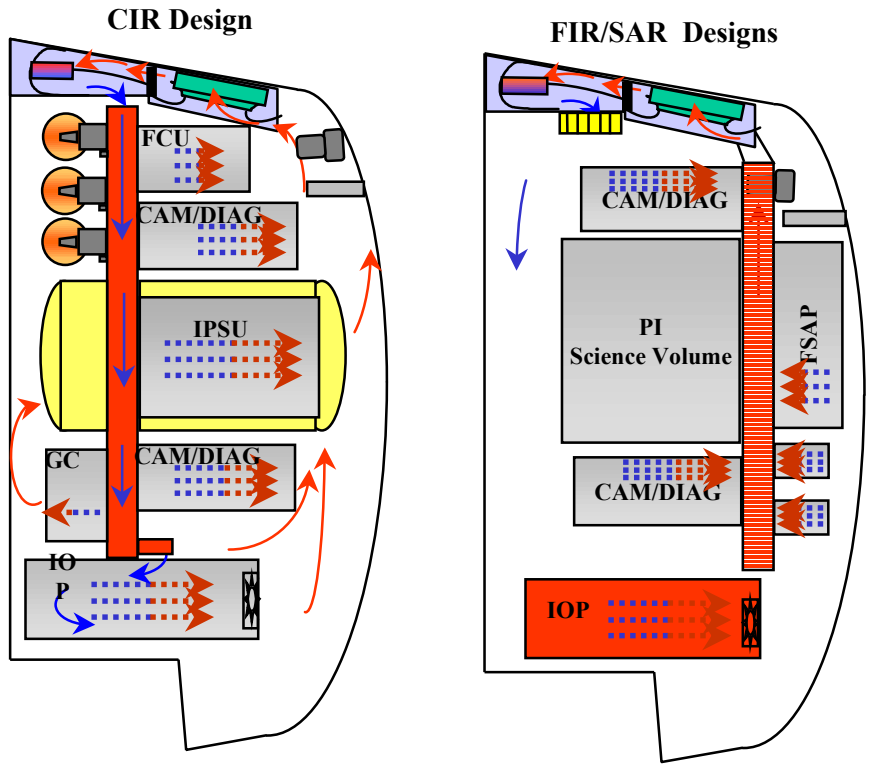
Fan Sub-Assembly



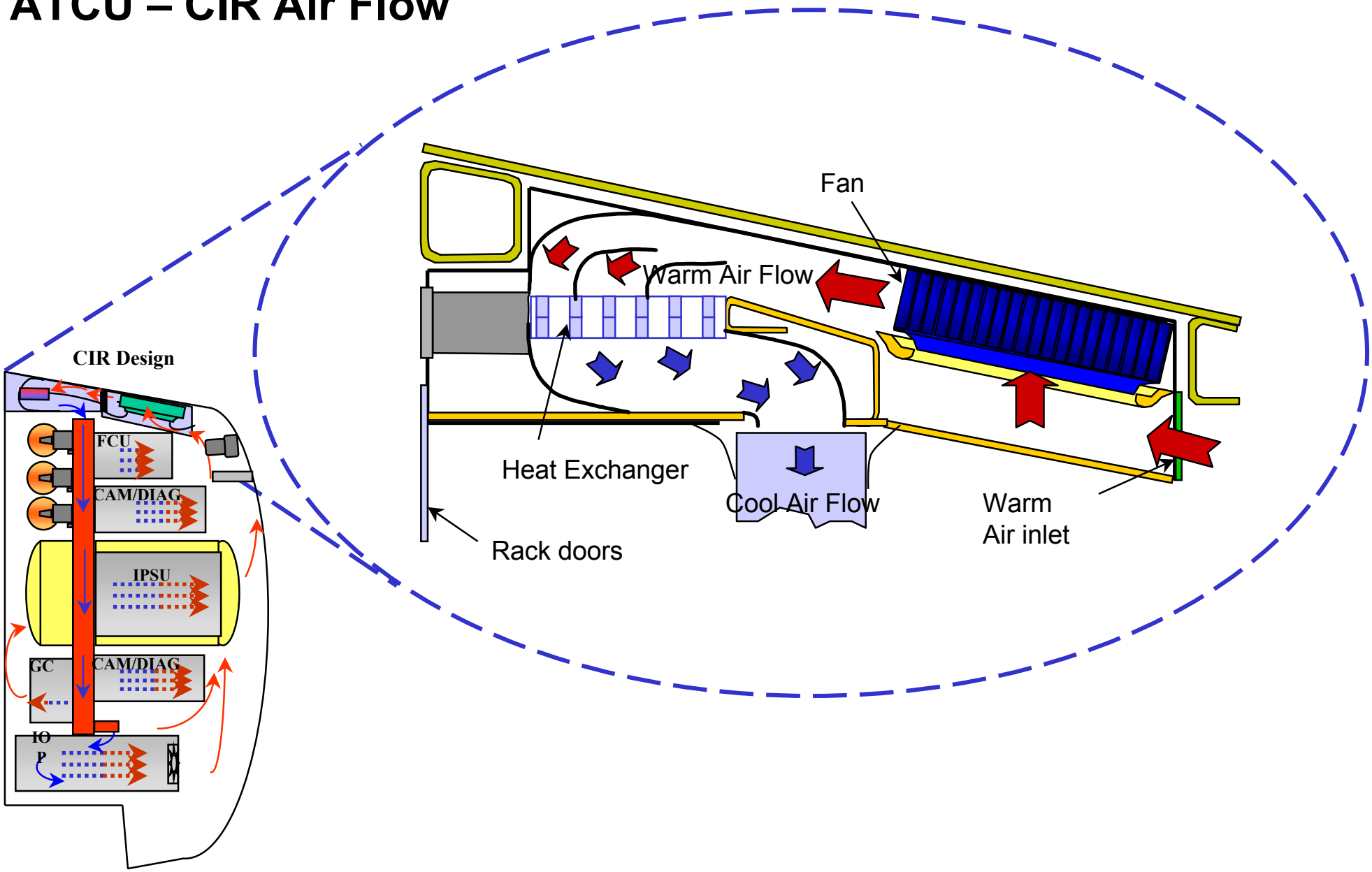
Heat Exchanger Sub-Assembly

ATCU Assembly Overview – Design Changes Since CIR PDR

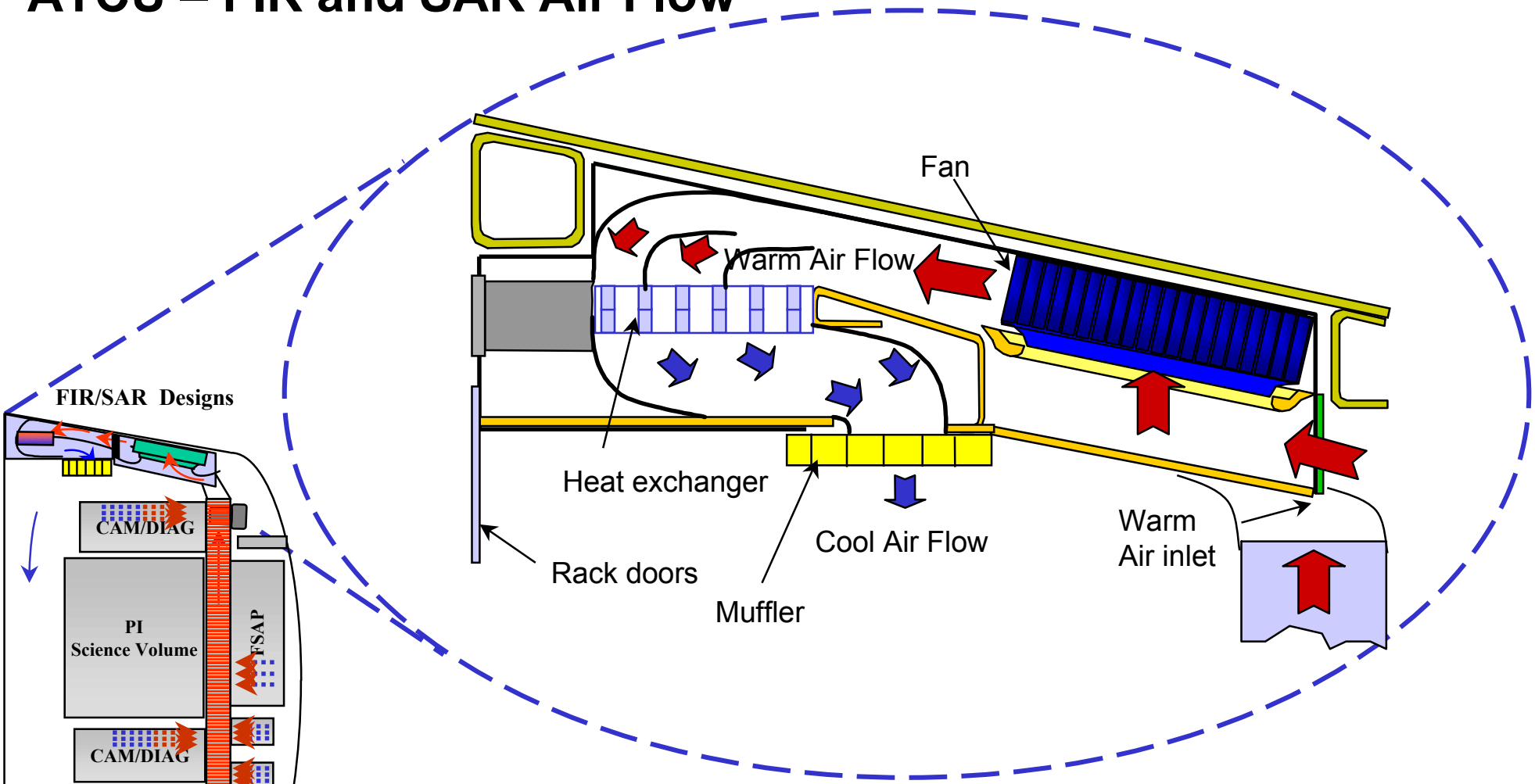
- Maximum Air Thermal Control Unit (ATCU) Subsystem commonality was preserved by modifying flow designs. Both designs use the Optics Bench as a flow duct.
  - CIR – Pressurize Duct
  - FIR/SAR – Suction Duct
- The ATCU will use a 2.25" depth heat exchanger (compared to 1.33" depth) to meet FIR/SAR/CIR cooling needs with one ATCU design.
- Rack Power Estimates Reports identify ATCU heat load for all basic experiments. The performance of the ATCU will be evaluated for each experiment configuration.



ATCU – CIR Air Flow



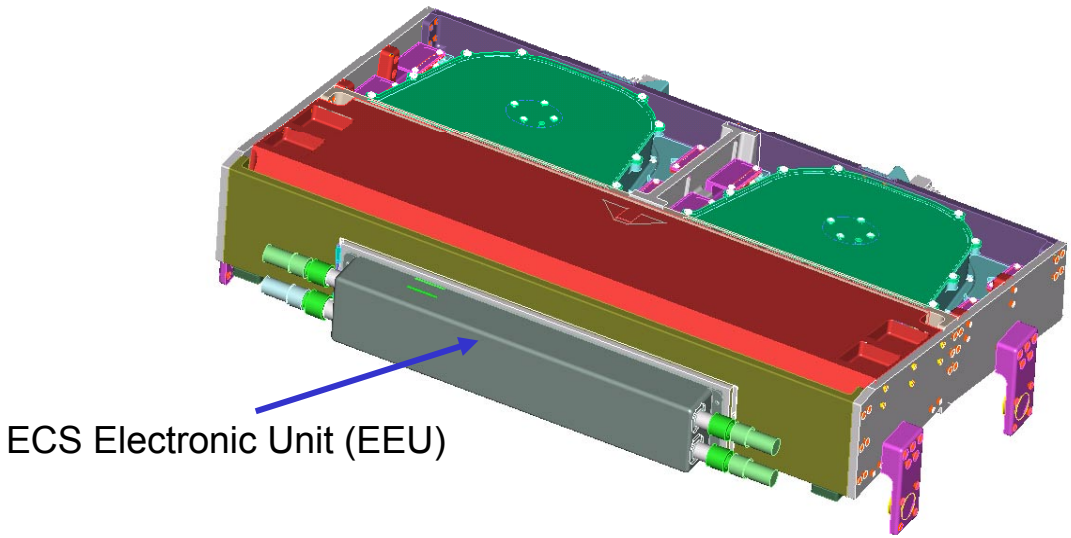
ATCU – FIR and SAR Air Flow



ECS Electronic Unit (EEU) Sub-Assembly

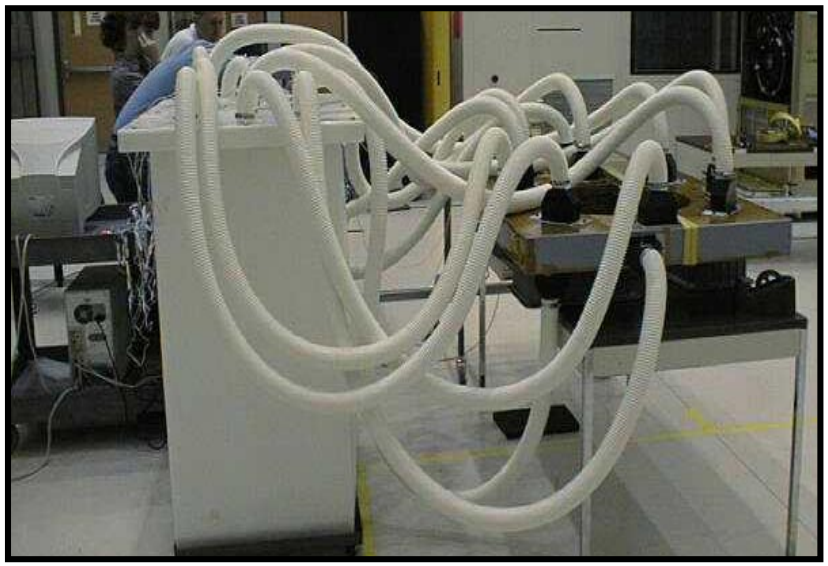
Function

- Controls the Air Thermal Control Unit (ATCU) and Water Thermal Control System (WTCS) systems via commands from the Input/Output Processor (IOP)
- Provides temperature and air flow data to the IOP
- Provides air flow data to Station
- The EEU is an Orbital Replacement Unit (ORU)



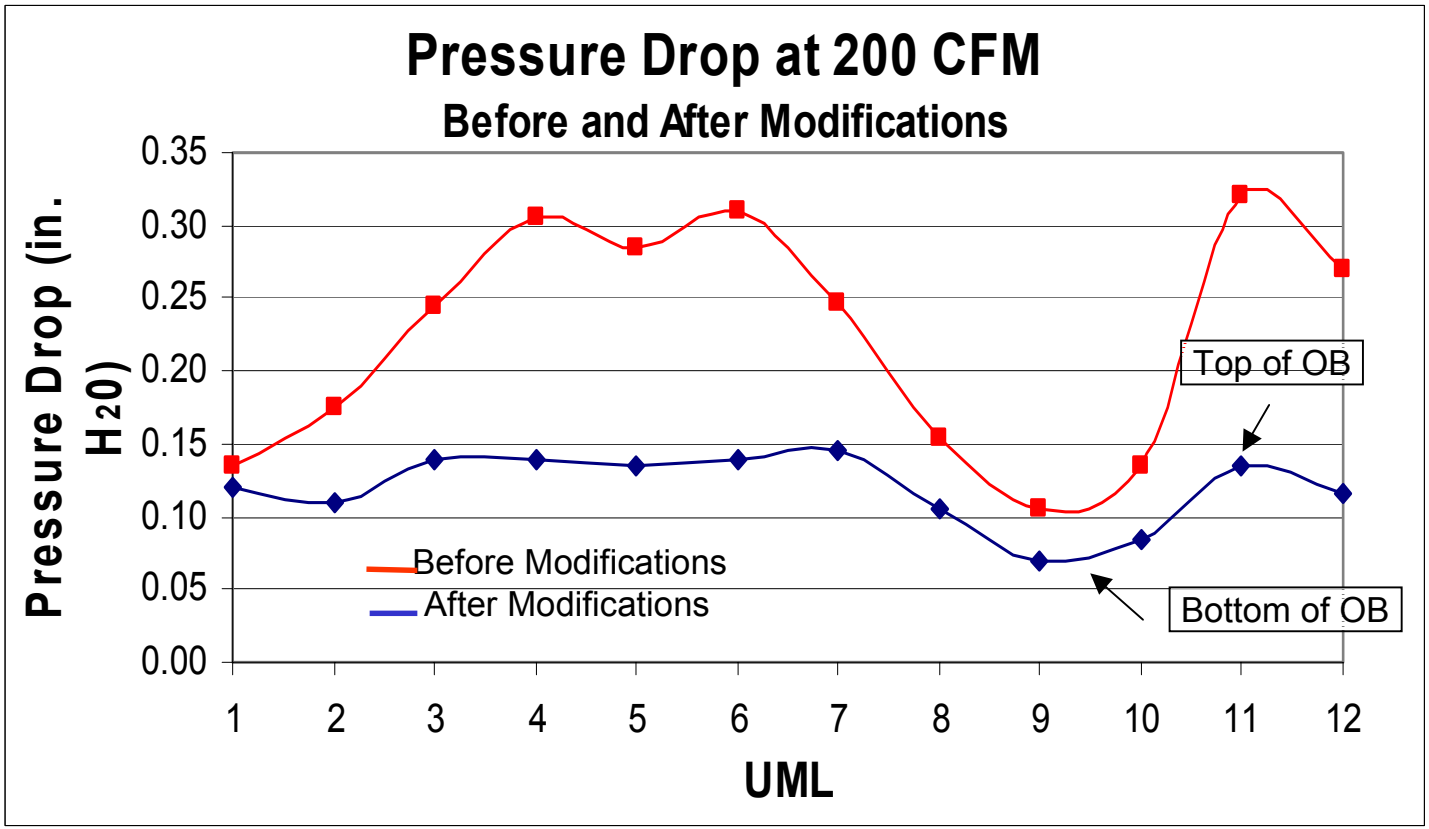
ATCU Testing

CIR Optics Bench Airflow



- Purpose
  - To determine the pressure drop associated with flowing air through the optics bench and the variations in pressure drop between UML sites
- Objective
  - Minimize total overall pressure drop through the optics bench
  - Minimize variations in pressure drop between UMLs
- Test Setup
  - Two tests were conducted on the stereolithography model of the CIR optics bench
    - First test: no modifications were made to the bench inner air path
    - Second test: ramps were added to the ribs and air openings inside the optics bench to reduce pressure drops associated with the air passing through sudden changes in cross sectional flow area
  - Pressure drop between individual UML sites measured with ducting routed to each UML

ATCU Testing: CIR Optics Bench Airflow – Continued



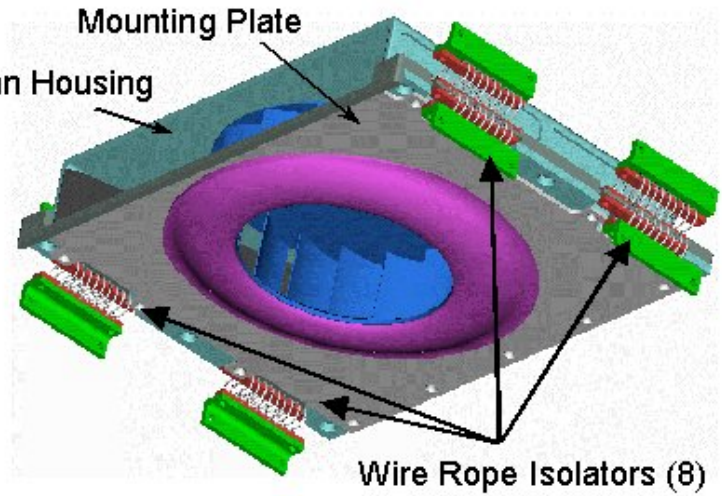
Results:

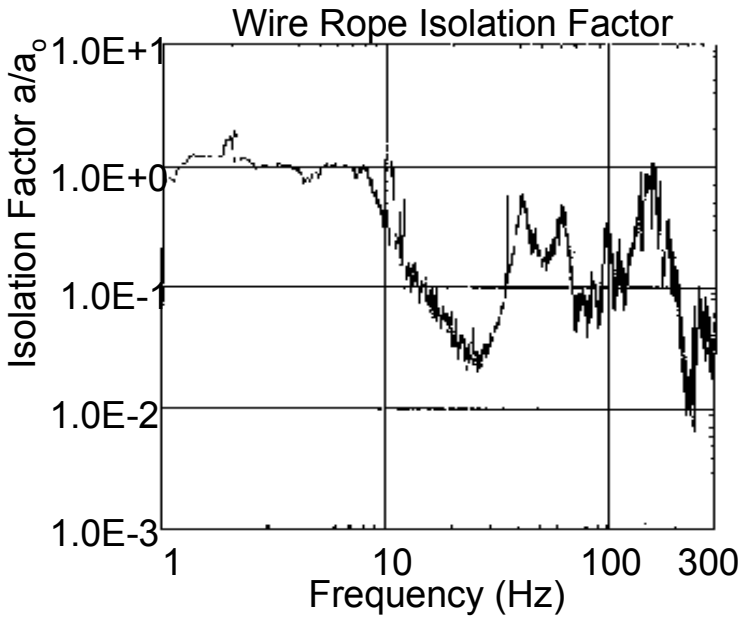
The addition of flow smoothing modifications to the bench caused a marked improvement of pressure drop from the top to the bottom of the optics bench (0.225 to 0.065 in. H2O), and a slight overall decrease in pressure.

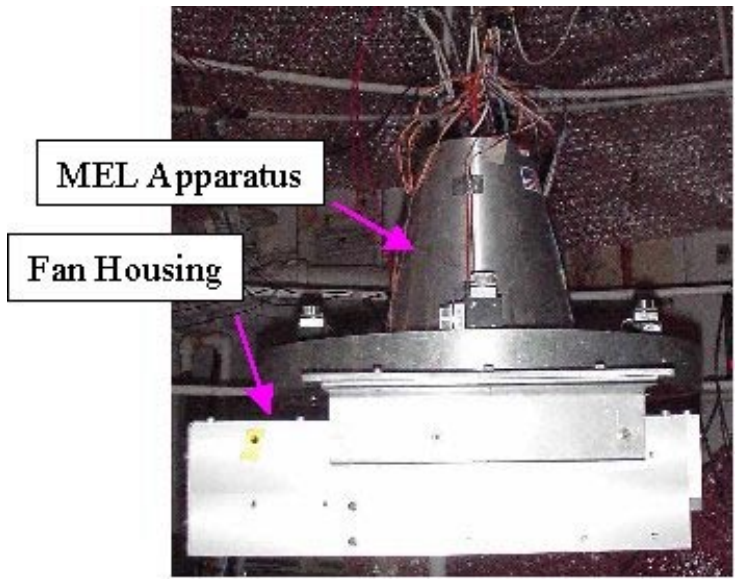
ATCU Testing – Continued

ATCU Fan Wire Rope Isolator Effectiveness

- Test performed to determine the effectiveness of wire rope isolators in damping microgravity disturbances
- A representative ATCU fan housing with isolators was tested at the NASA Glenn Microgravity Emissions Lab (MEL)
- Results show that the isolators were effective in the the range as the ATCU fans (20-40 Hz)







ATCU Testing – Continued

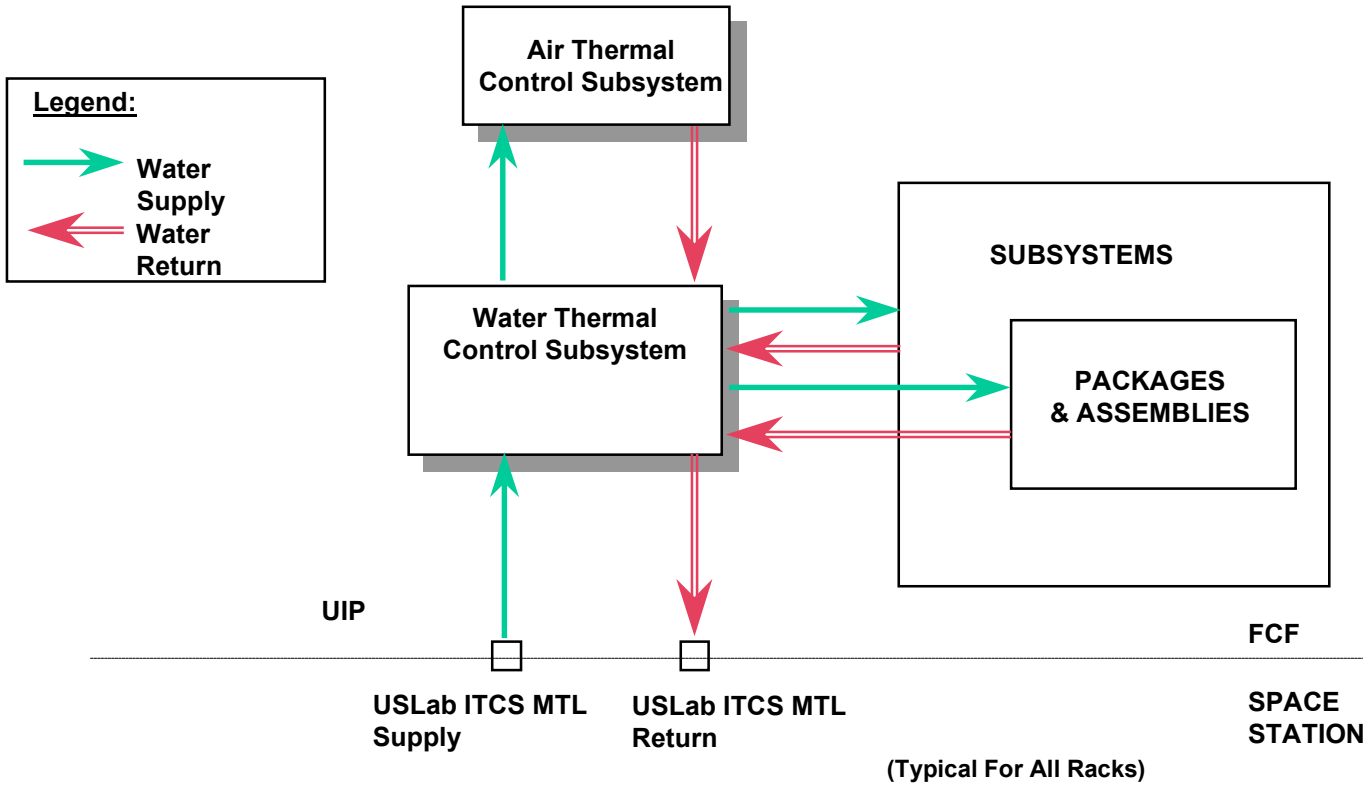
ATCU Fan Acoustic Test

- Preliminary testing shows fan requires noise reduction
- Fan measured 70 dBA – Less than 49 dBA is required for a continuous noise source

- Methods that will be investigated to bring fan into compliance:
  - Proper dynamic balancing of fan and rotors; selection of highest quality bearing and grease and electrically commutated motor
  - Placement of sound absorbing and/or transmission blocking material
- Future Testing
- Engineering Model (EM) Fan Assembly, ATCU, and Fully Integrated Rack

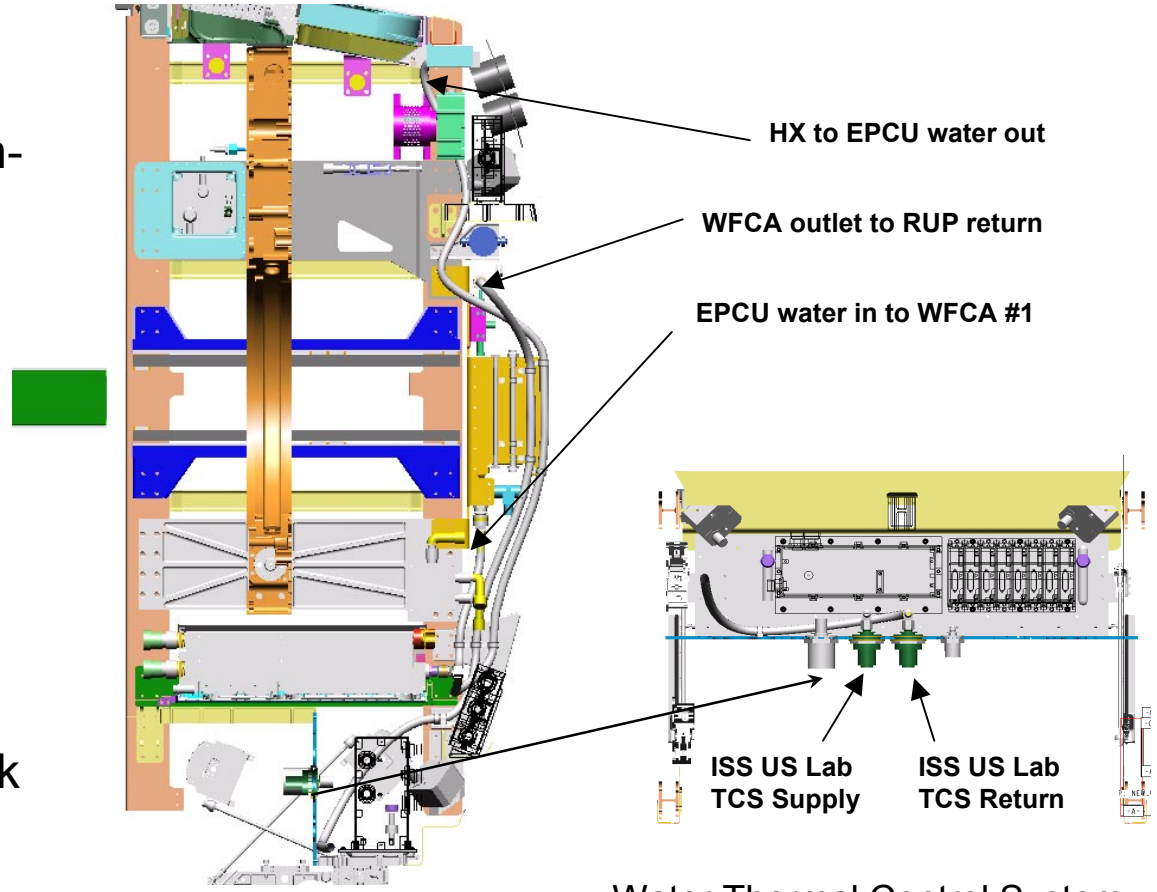
Water Thermal Control System (WTCS) Function

- The WTCS performs thermal control functions associated with the operation of the facility.
- The WTCS provides cooling of all FCF equipment by removing all the waste thermal energy generated by FCF systems and transferring it to the International Space Station (ISS) Internal Thermal Control System (ITCS) Moderate Temperature Loop (MTL).



Water Thermal Control System (WTCS)

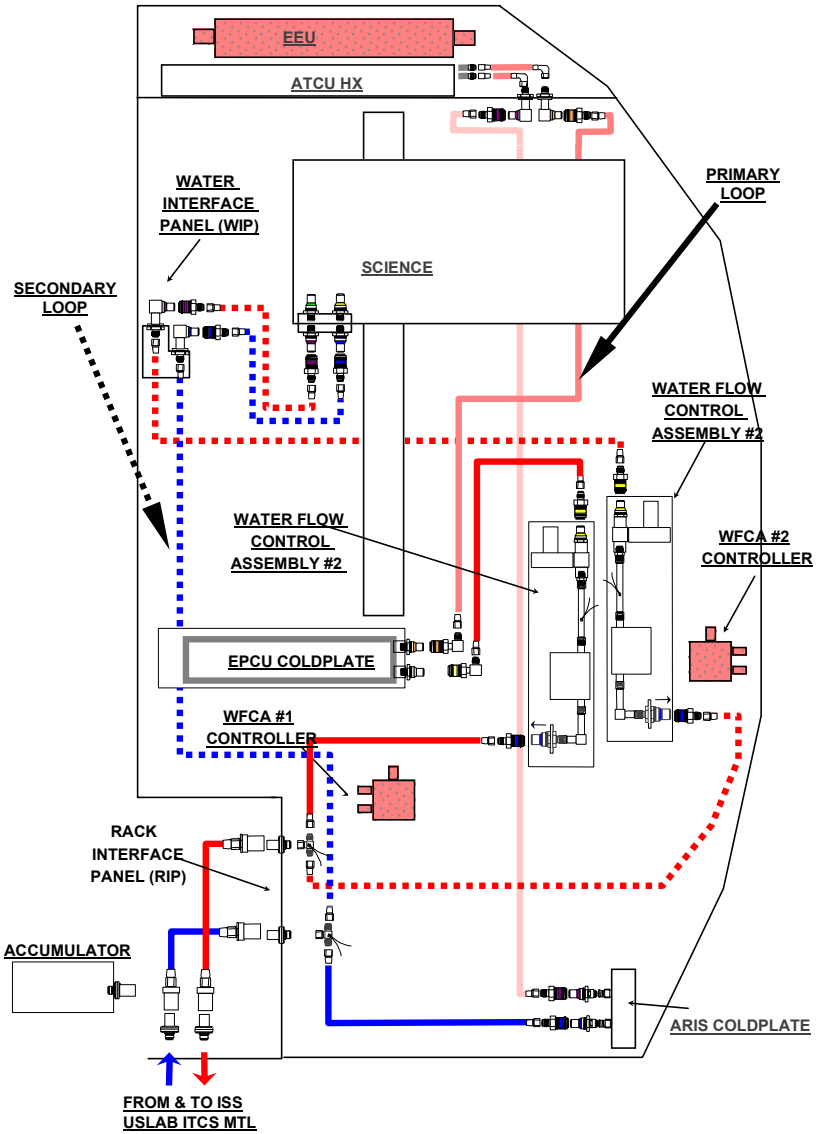
- Distributed network of plumbing to carry supply and return flow to and from interfaces with science and non-science packages including the Air Thermal Control Unit (ATCU) air to water heat exchanger.
- Each rack interfaces with the ISS ITCS MTL supply and return at the rack Utility Interface Panel (UIP). These services are routed to the Rack Utility Panel (RUP) using flexible umbilicals, which are part of and provided by the rack Active Rack Isolation System (ARIS).
- Beyond the RUP, separate networks are provided for science and non-science hardware.



Water Thermal Control System (WTCS) Rack Utility Panel (RUP) Interface

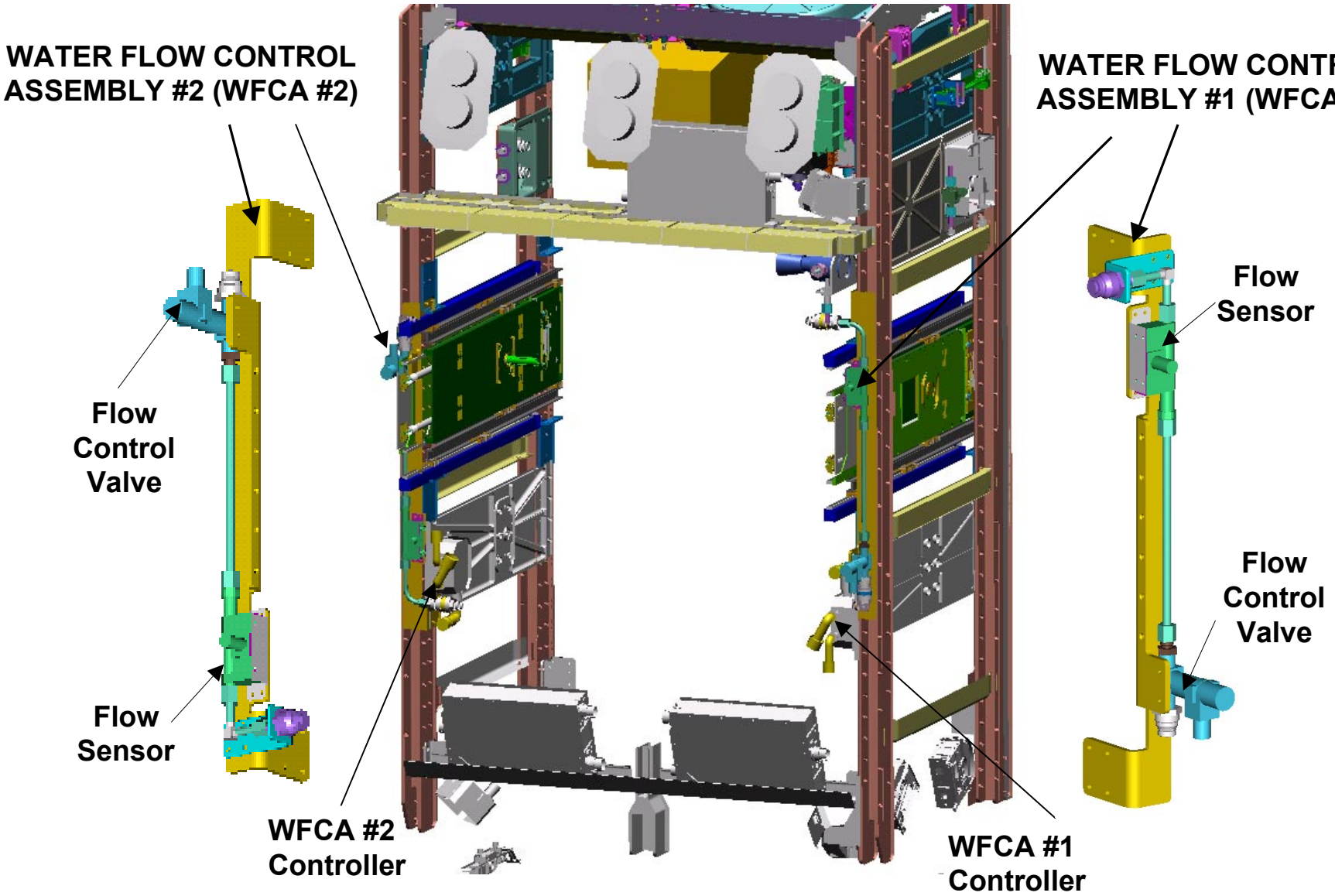
Water Thermal Control System (WTCS) Capabilities

- Science hardware interfaces with the WTCS at the Water Interface Panel (WIP) using flexible umbilicals with Quick Disconnects (QDs).
- Nonscience hardware is plumbed in series in order to conserve ISS ITCS MTL water flow rate. These packages interface to the WTCS through QDs.
- Each WTCS loop is capable of delivering up to 300 lbm/hr of water flow rate. The water flow rate is a function of the total power being dissipated by each rack. ISS ITCS MTL requirements dictate the amount of water available. This flow rate corresponds to about 97.5 lbm/h per 1 kW of power.
  - With a combined maximum of 600 lbm/h, the maximum cooling capability for each rack is just over 6 kW with a corresponding inlet-outlet temperature of 65 to 100°F (18.3 to 37.8°C).



WTCS Water Flow Control Assembly (WFCA)

(Common Buy with MSRR-1/MSFC)

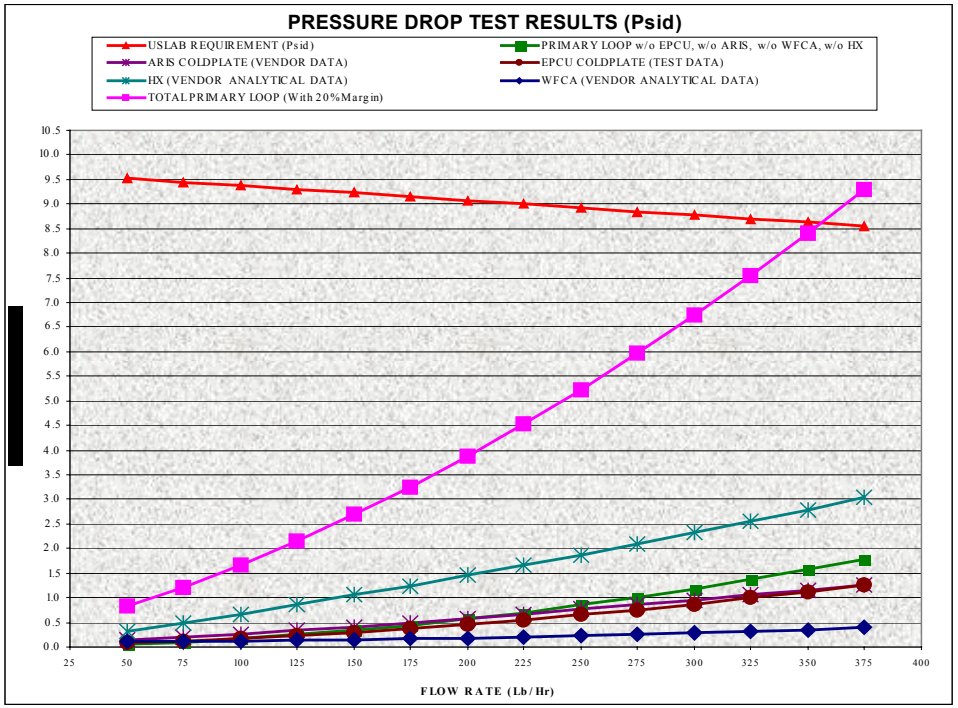


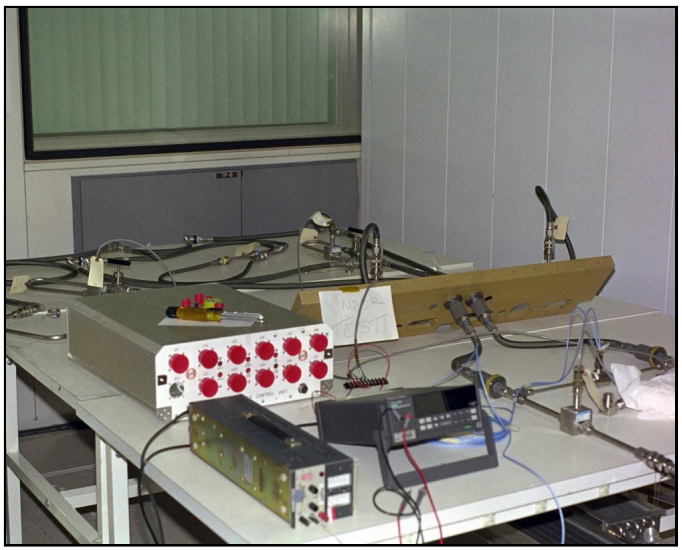
Water Thermal Control System (WTCS) Testing

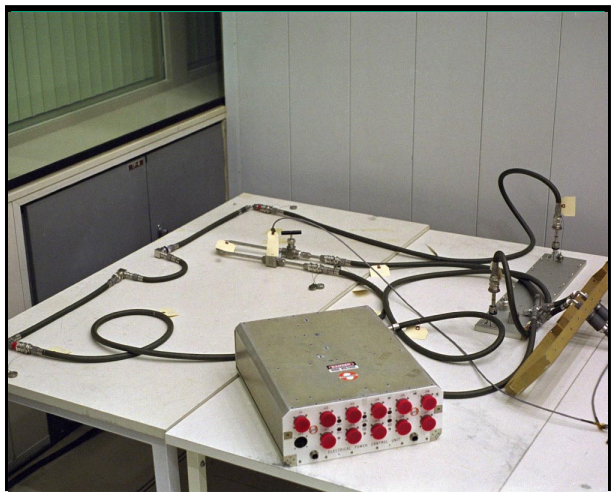
WTCS Engineering Model

- Purpose
  - To investigate and resolve technical issues in support of the WTCS design
- Results
  - The total subsystem primary loop pressure drop at the expected maximum flow rate of 300 lb/hr is 6.75 psid, well within the maximum pressure drop requirement of 8.77 psid

Full Report: CIR-TEST-0018







WTCS Testing – Continued

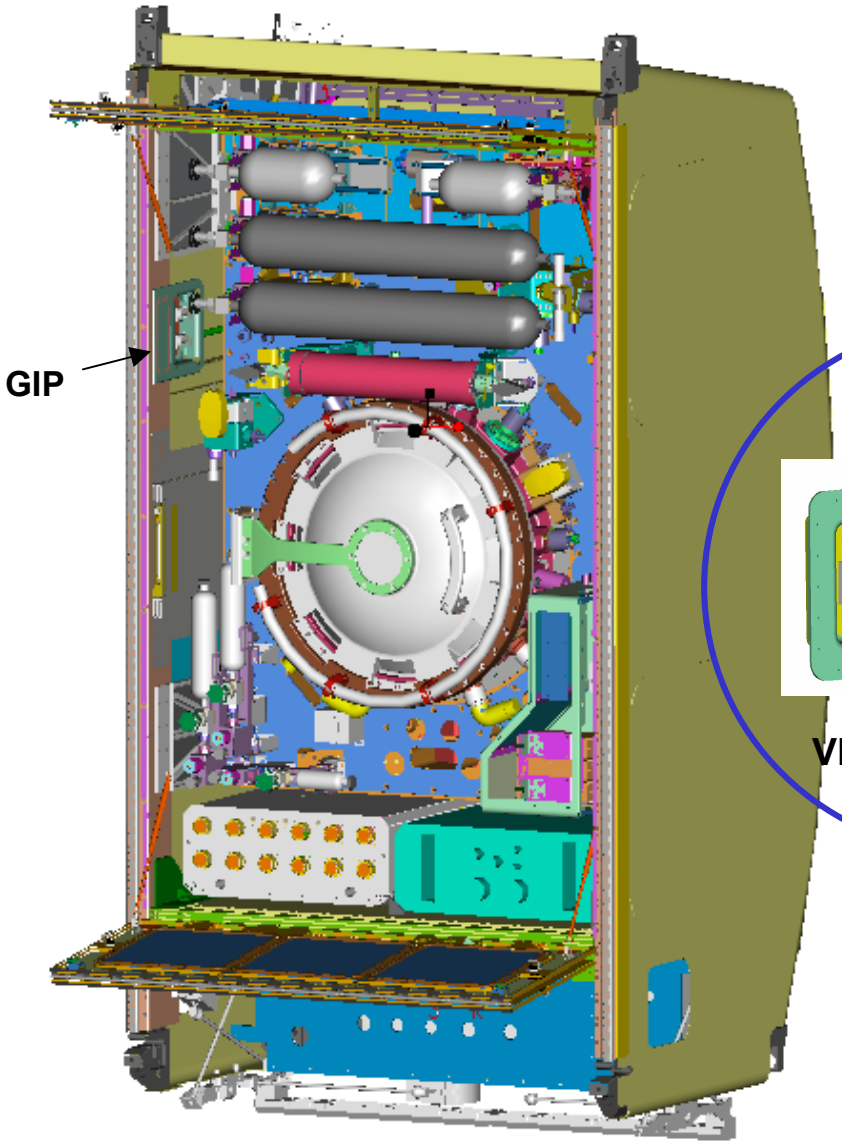
Electromagnetic Interference (EMI)

- A development Water Flow Control Assembly (WFCA) from Preece was tested for conducted emissions and exceeded the limit at about 24 MHz
  - Vendor (Preece) has been informed of the problem and a recommendation was made for a solution

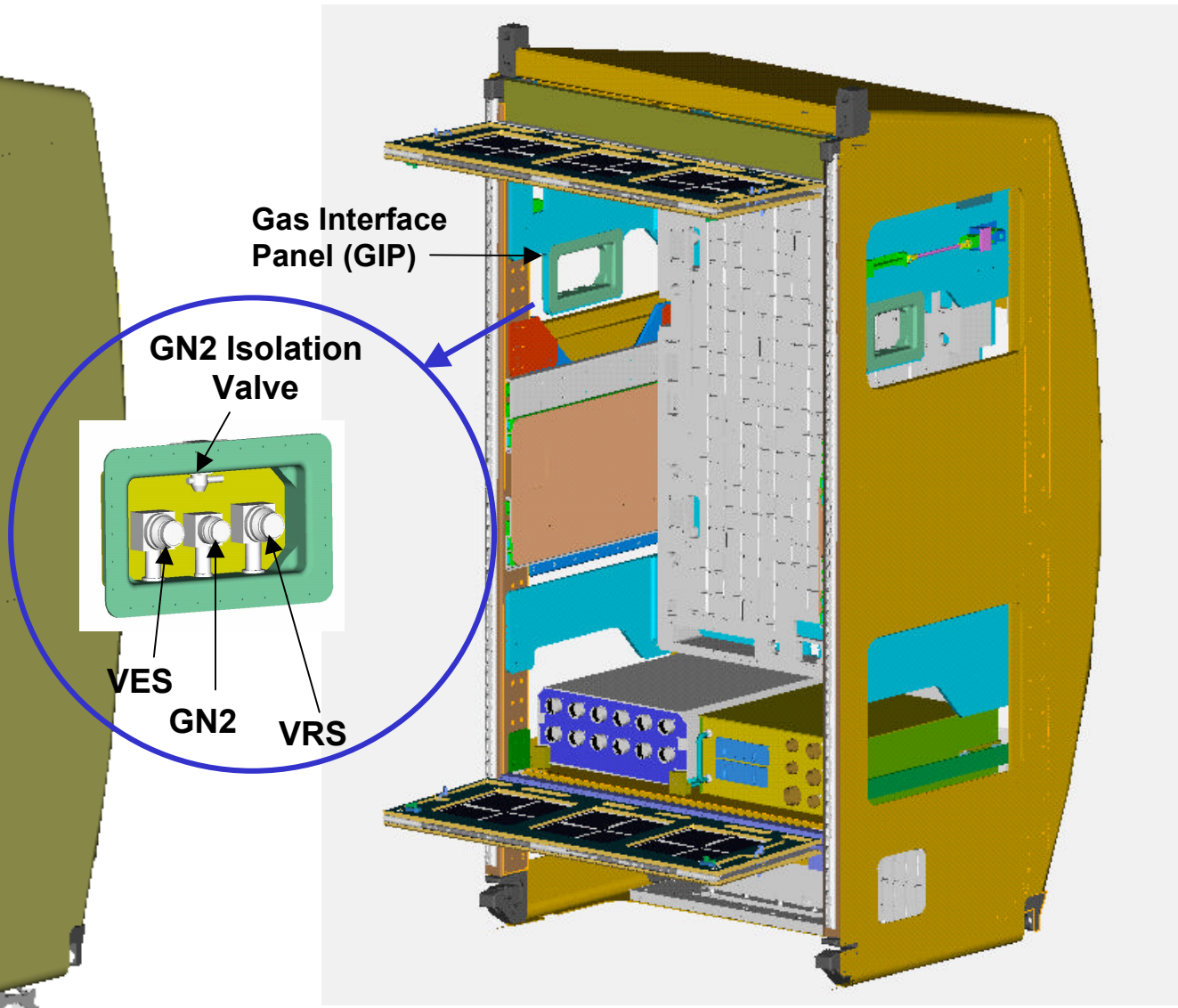
Gas Interface System (GIS) Function

- **Gaseous Nitrogen**
  - Provides interface to ISS Gaseous Nitrogen (GN2) resource
    - Operating pressure: 517 to 827 kPa
    - 90 SLM directly from ISS or 30 SLM via mass flow controller
    - Operating temperature: 15.5 to 45°C
  - Available for CIR, FIR and SAR
- **Vacuum Exhaust System (VES)**
  - Provides interface to ISS VES
    - Designed to reach 0.13 Pa within 2 hours
  - Available for CIR, FIR and SAR
- **Vacuum Resource System (VRS)**
  - Provides interface to ISS VRS
    - Maintains pressure of 0.13 Pa of a throughput of 1.3x10-3 torr*liters/second
  - Available for FIR and SAR
  - QD on Rack Utility Panel (RUP) available for CIR

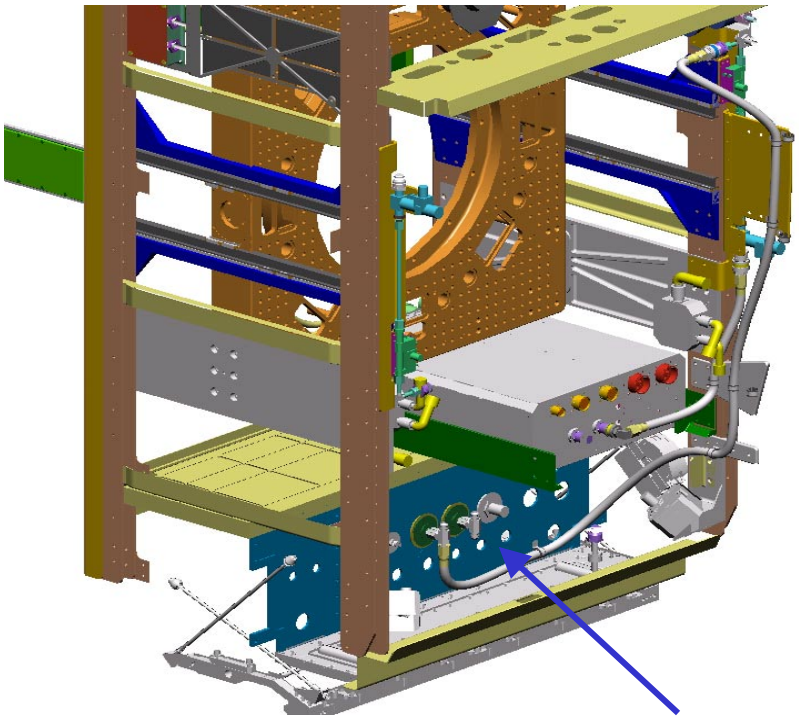
Location of GIS in CIR

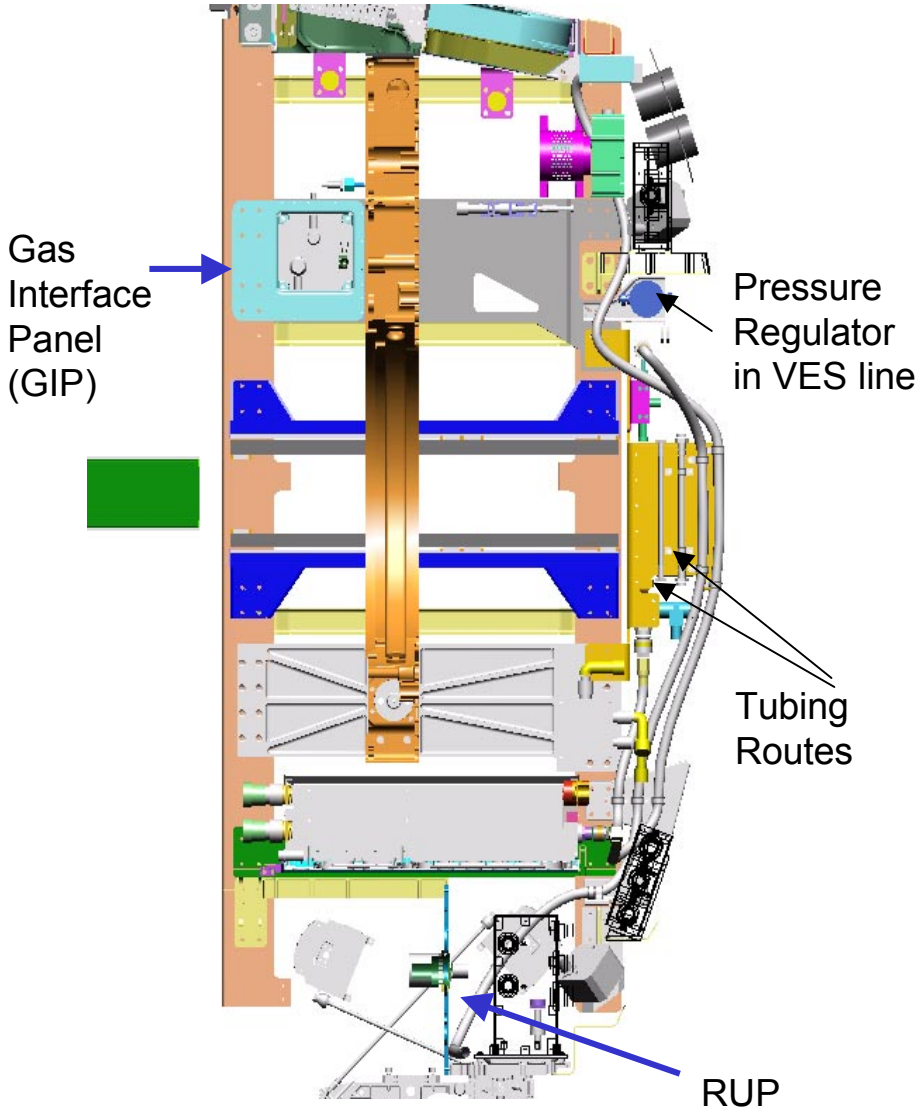


Location of GIS in FIR and SAR



Gas Interface System (GIS) in CIR

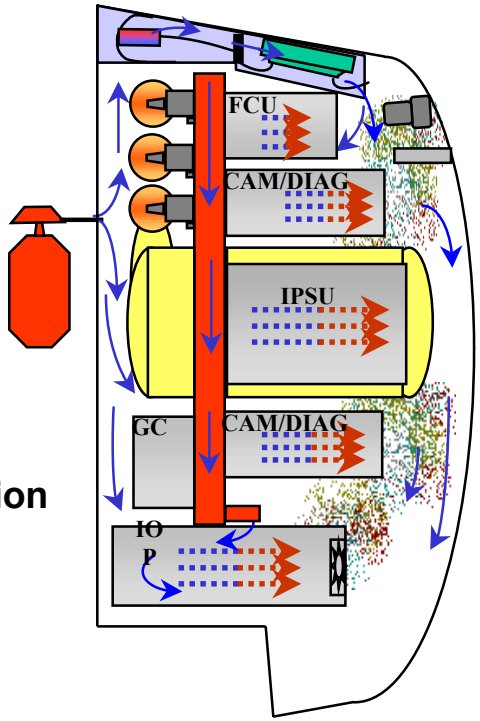




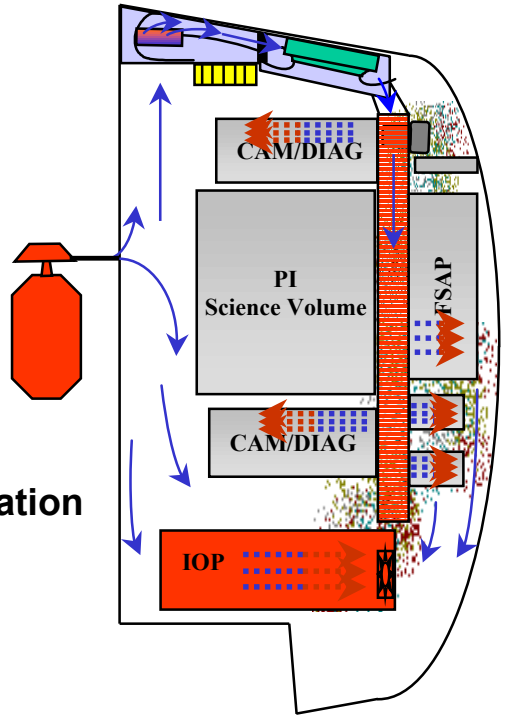
Fire Detection and Suppression System (FDSS) Function

- Detect the presence of forced air in an integrated rack
- Detect smoke in an integrated rack
- Send a signal to ISS if smoke is detected
- Provide an access port for deployment of the fire suppression device

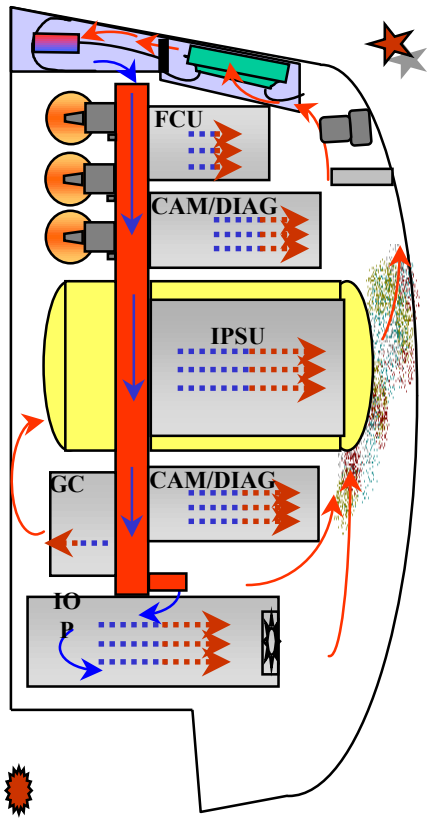
CIR Implementation



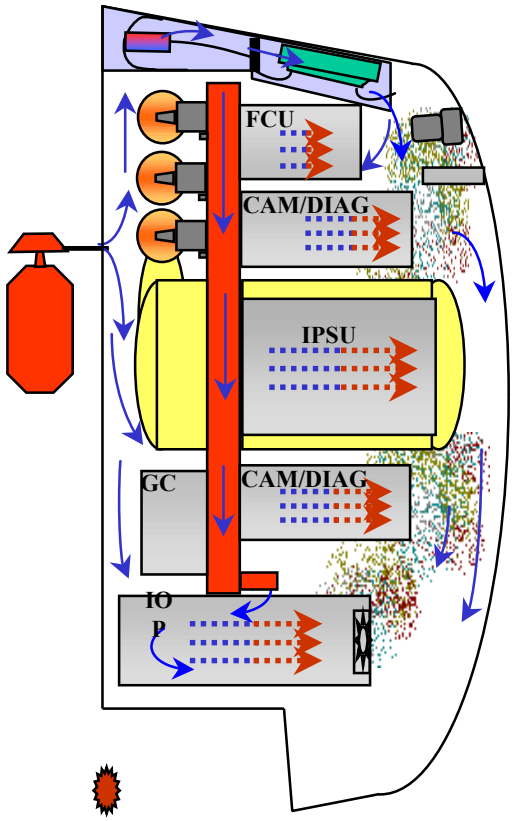
FIR & SAR Implementation



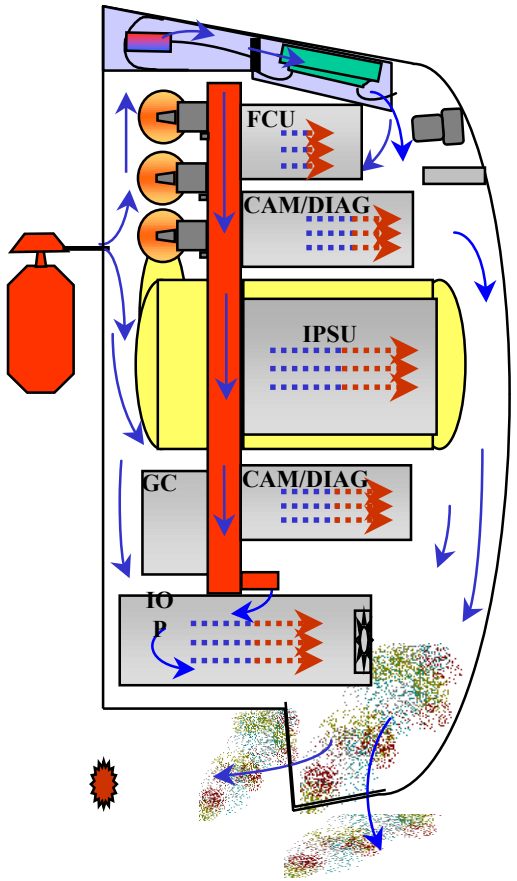
Fire Detection and Suppression System (FDSS) Function – CIR



Step 1. Smoke Detector indicates a fire event signals ISS systems which shut off power and alerts the crew.



Step 2. Crew inserts and dispenses portable fire extinguisher (PFE) into access port in rack door.



Step 3. Fire event is extinguished.

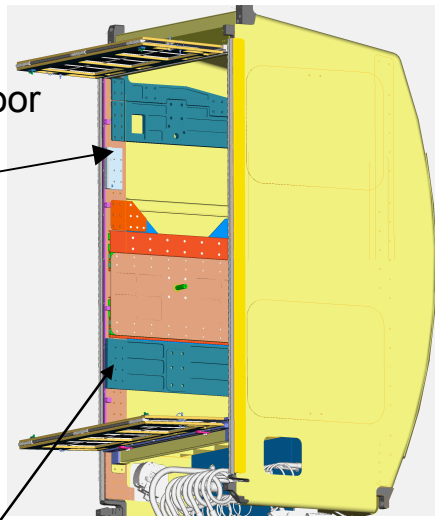
Common Systems Structural Subsystems

- Rack Doors
- Optics Bench Slides
- Air Thermal Control Unit (ATCU) Rack Attachment Bracket
- Center Post/Electrical Power Control Unit (EPCU) and Input/Output Processor (IOP) Attachment
- Optics Bench Active Rack Isolation System (ARIS) Pins

Rack Doors

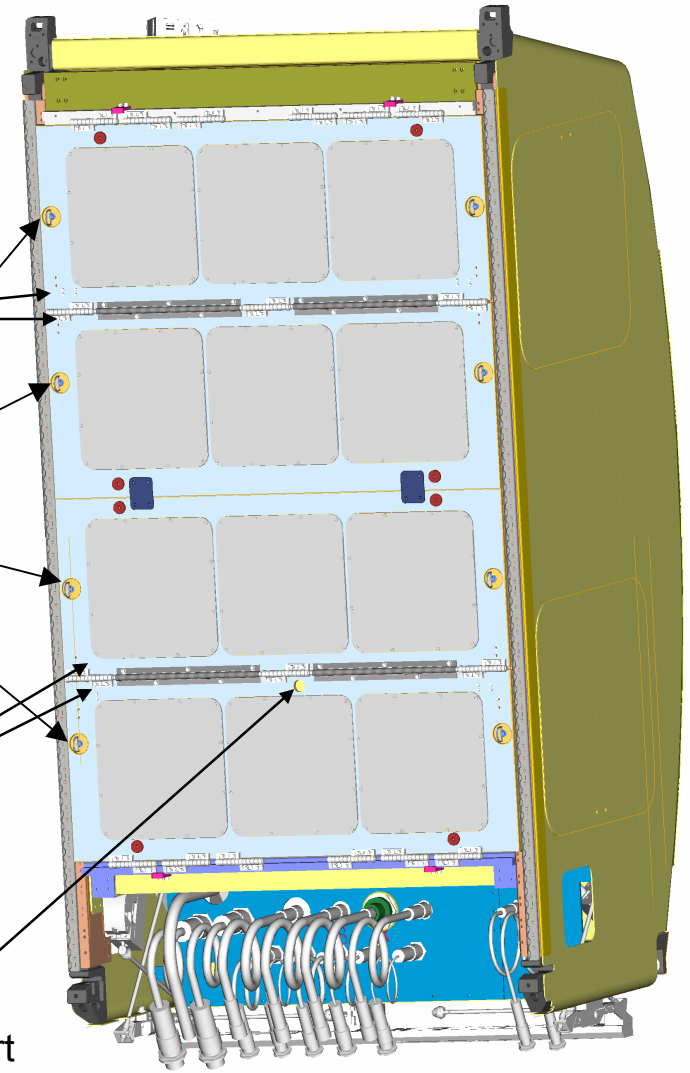
Securing of Door on orbit

- ¼ turn Camlocks
- Bail-style handle



Upper Door Launch Support Plate

Lower Doors are mounted to Lower Optics Bench Support Plate



Structural Launch Fasteners Removed on-orbit, Plugs installed

¼ Turn Camlocks

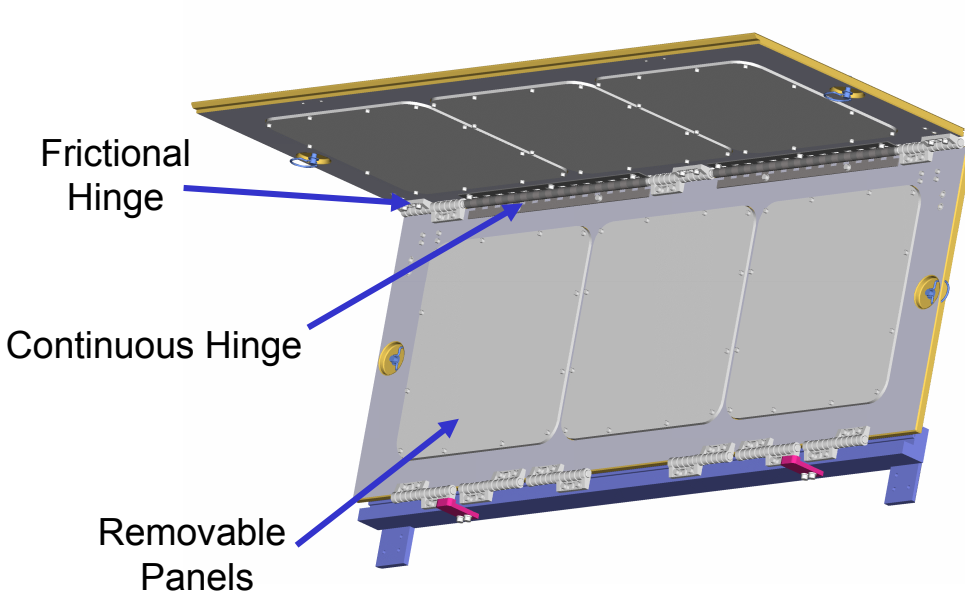
Structural Launch Fasteners Removed on-orbit, Plugs installed

Fire Extinguisher Port

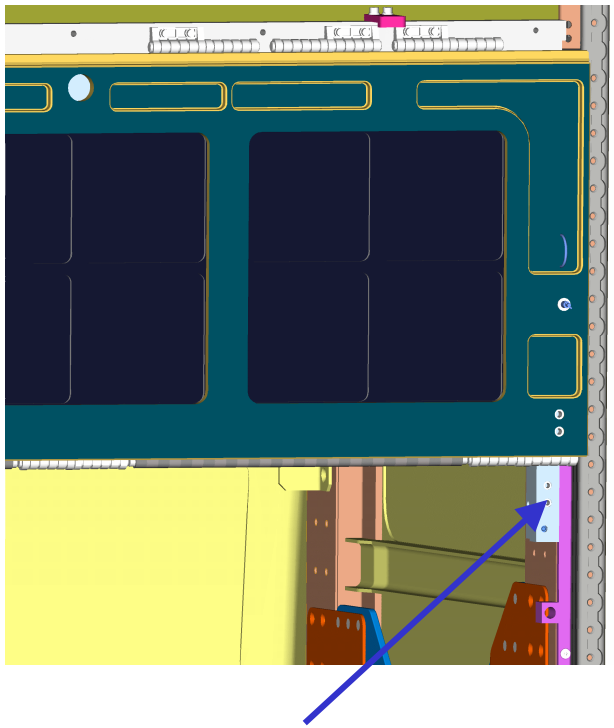
Rack Doors – Continued

Laser safety interlock switch

- Texas Instruments plunged activated switch
- Located on right side of rack
- Upper Door Assembly must be opened first to access inside rack



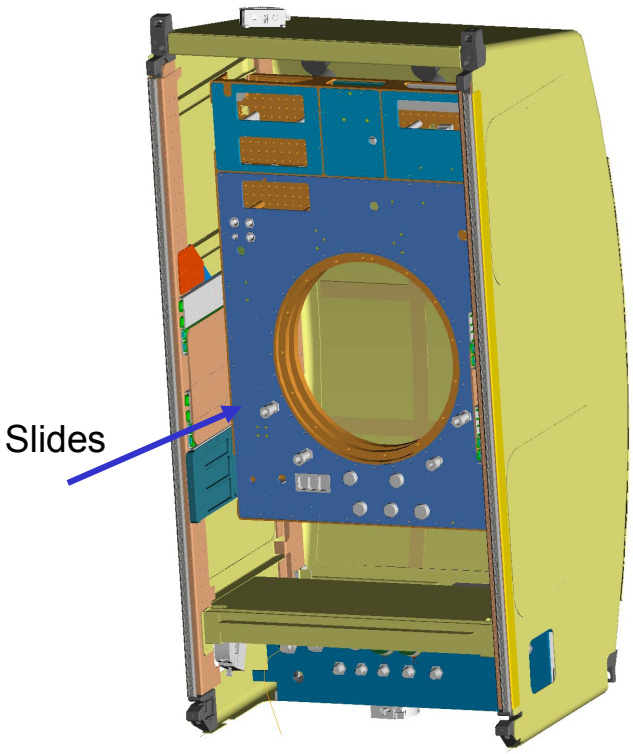
Upper Door Assembly



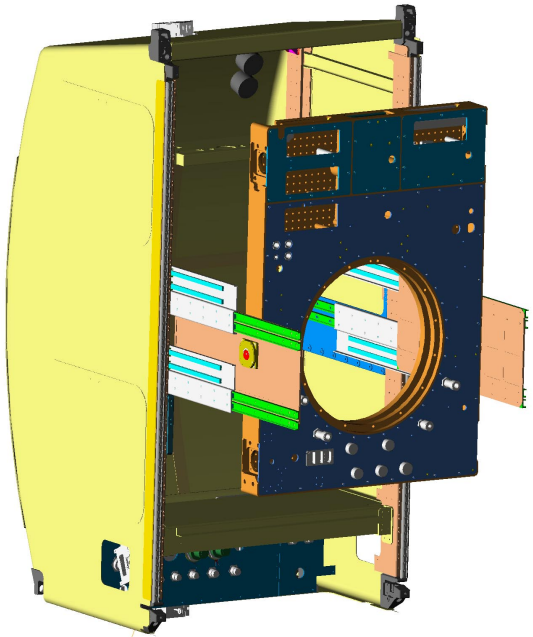
Optics Bench Slides

Function

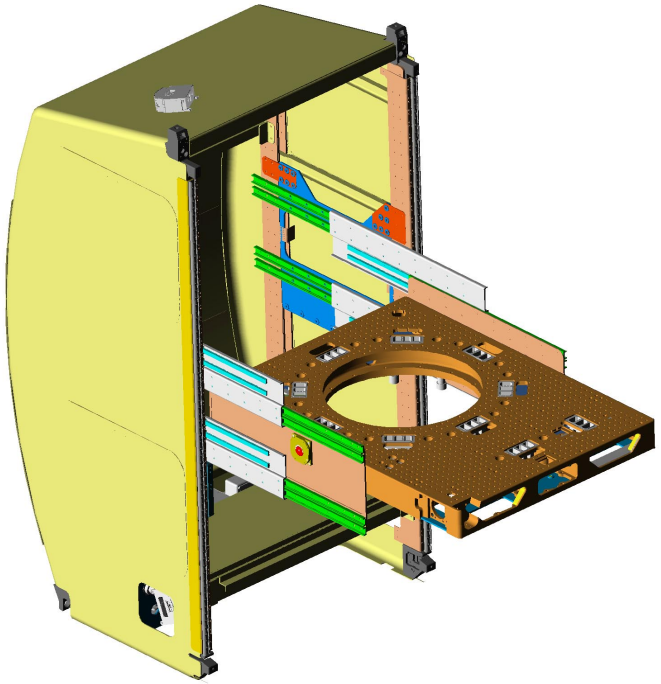
- Allows controlled Optics Bench translation and rotation
- Provides access to back of Optics Bench
- Mounted to International Standard Payload Rack (ISPR) Posts and Lower Optics Bench Launch Restraint Plate
- Interfaces to Optics Bench at pivot point
- Allows Optics Bench translation out of rack
- Rotational brake allows controlled rotational deployment of the Optics Bench
- Designed so no Ground Support Equipment (GSE) needed for on-ground translation
- GSE required for on-ground rotation



Optics Bench Slides – Continued



Optics Bench (CIR shown)
at Full Translation

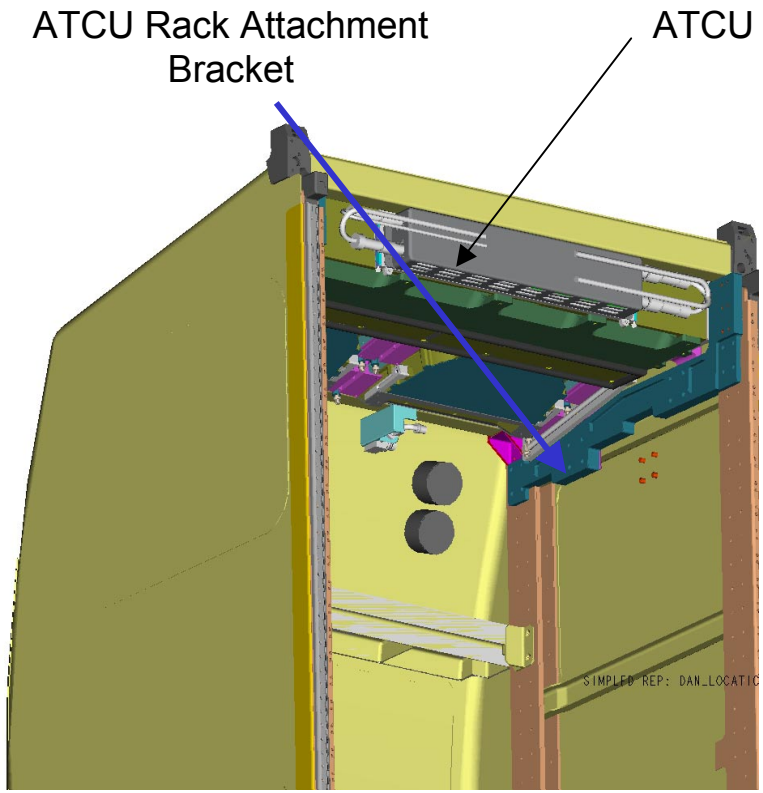


Optics Bench (CIR shown)
at Full Rotation

ATCU Rack Attachment Bracket

Function

- Air Thermal Control Unit (ATCU) Rack Attachment Bracket is used to interface the ATCU with the International Standard Payload Rack (ISPR) posts
- Cross Member Attachment Interface for Rack Doors are mounted between brackets
- Once on-orbit fasteners are removed from holding the ATCU to the bracket
  - Removal of fasteners allows passive vibration isolation material to dampen microgravity disturbances generated by the fans
- Vibration isolation material – Sorbothane, a commercially available material used for vibration isolation

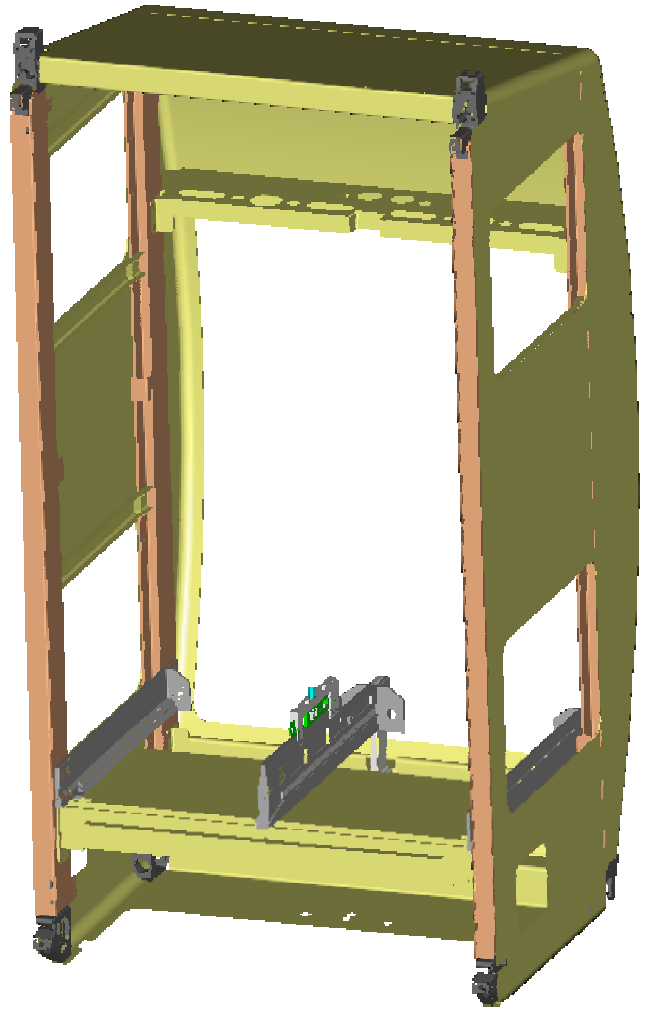


ATCU Mounted in the ISPR

Center Post/EPCU and IOP Attachment

Function

- Provides attachment for the Electrical Power Control Unit (EPCU) and Input/Output Processor (IOP)
- Provides mounting structure for Lower Optics Bench Active Rack Isolation System (ARIS) Pin Mechanism
- Utilizes existing attachment points on International Standard Payload Rack (ISPR)
- Left side interfaces with EPCU, includes slide, rear pin receptacle and launch bracket mounting
- Right side interfaces with IOP, including slide, rear pin receptacle and launch bracket mounting

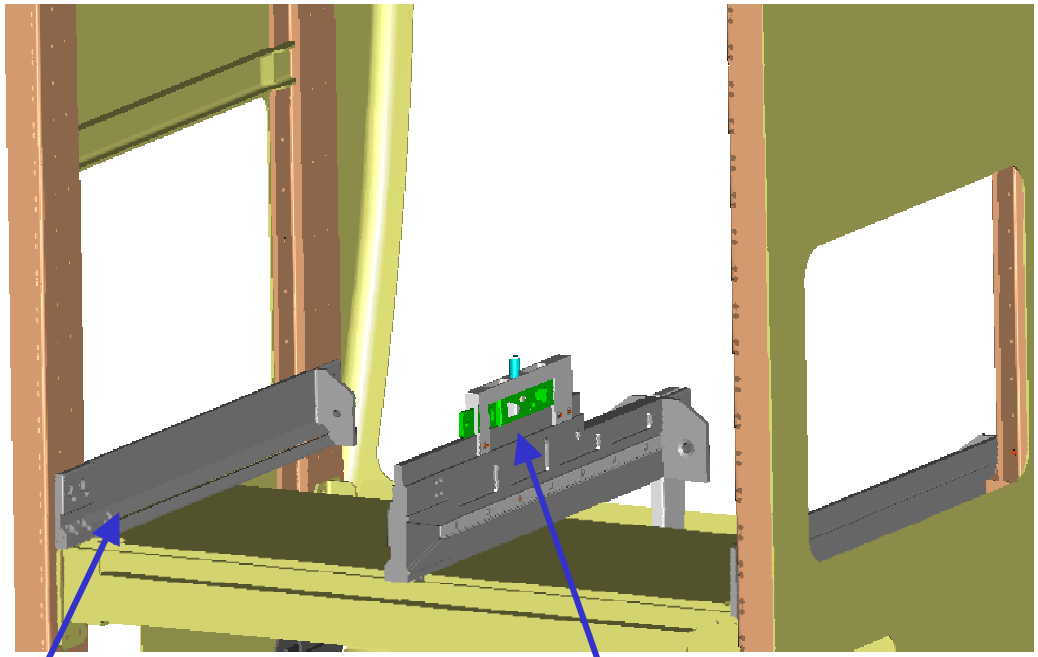


Optics Bench ARIS Pins

Function

- Constrains the Optics Bench on-orbit during Active Rack Isolation System (ARIS) operation
- Pins are retractable to allow Optics Bench deployment out of the Rack
- Pins are not a structural element for launch loads
- Upper pin mechanisms (one each side) mounted to Upper Optics Bench Launch
- Restraint Plates
- Lower pin mechanism mounted to Center Post
- All pin deployment mechanism are common to all racks
- Crew interfaces are specific to each rack due to Optics Bench location in the rack

Optics Bench ARIS Pins – Continued

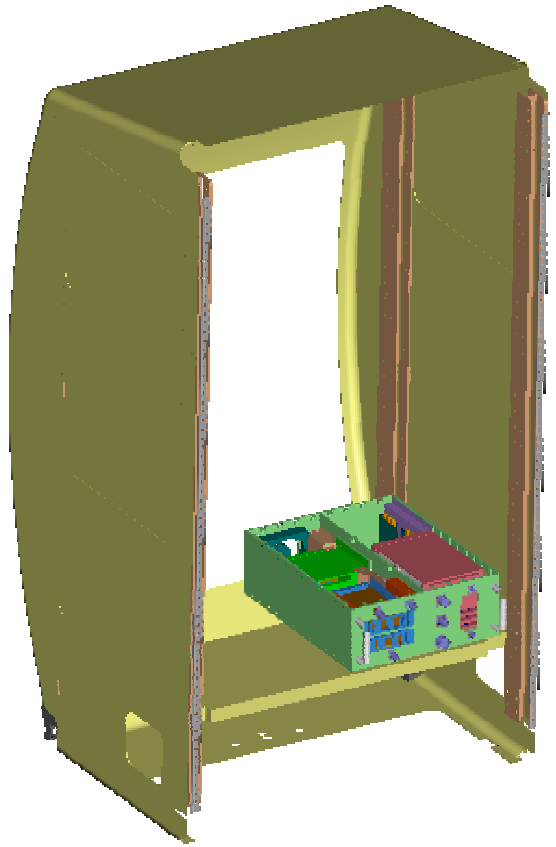


EPCU Rail/Launch Restraint Bracket Interface

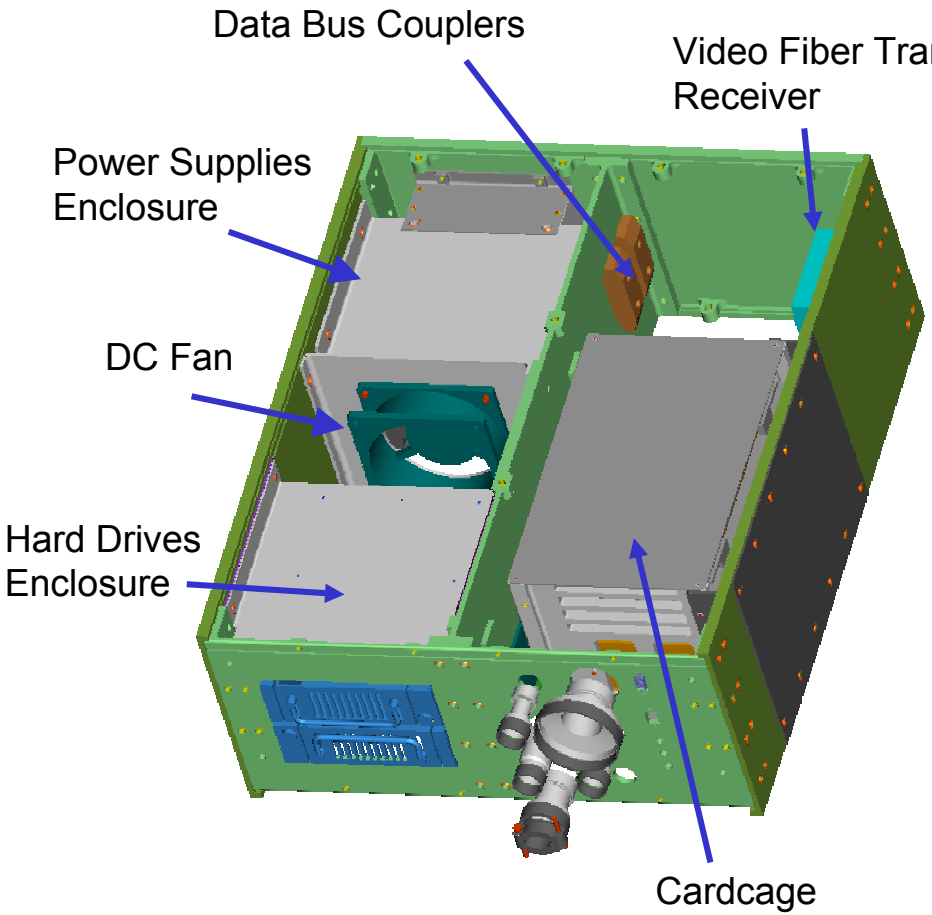
Center Post with IOP Rail and Optics Bench Lower ARIS Pin Mechanism (CIR)

Input/Output Processor (IOP) Functional Capabilities

- MIL-STD-1553B – Low Rate Data Link (LRDL) interface and EPCU/ARIS control
- Ethernet switch – Medium Rate Data Link (MRDL) interface
  - Fiber optic interfaces for three rack FCF LAN
- High Rate Data Link (HRDL) interface for data downlink
- Analog video routing - Video switch and CVIT
  - Fiber optic converters for rack to rack analog video
- Power distribution and communications with SAM-FF
- CANbus - independent channel for Optics Bench and Environmental Control System (ECS) C&C and H&S data collection
  - Fiber optic converter for rack to rack diagnostic communications
- Removable hard drives for storage of science data
- Sync signal generation and distribution for synchronizing diagnostics
  - Fiber optic converters for rack to rack sync bus
- Laptop interface



Input/Output Processor (IOP)



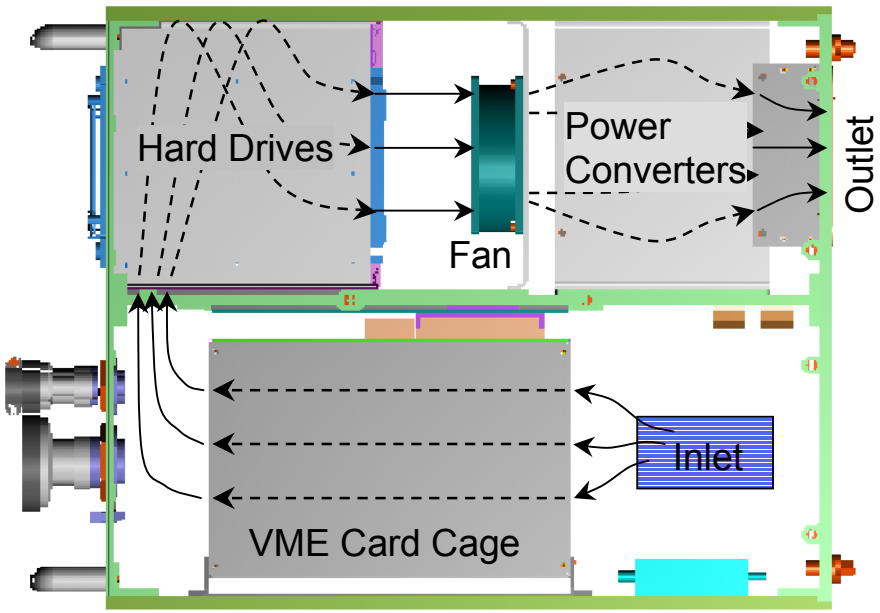
IOP Stereolithography Model

IOP Stereolithography Airflow Test

Objectives

- Investigate local air velocities, flow paths and CFM percentages through openings
- Verify Input/Output Processor (IOP) Engineering Model (EM) predictions

The IOP Stereolithography Airflow Test Report is documented in FCF-TRT-0077



IOP Airflow Path

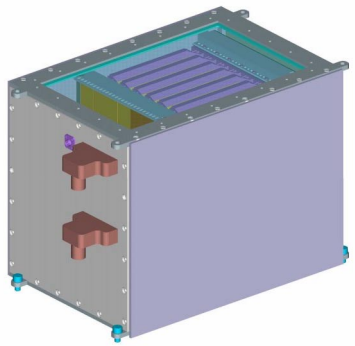
Results

- Good seals will be important in the EM to prevent air leakage
- A small orifice plate will be added to the EM to correct a deadzone over the top hard drive
- The pressure drop across the IOP was within 5% of predicted values
- CFM percentages through openings all within 10% of calculated values

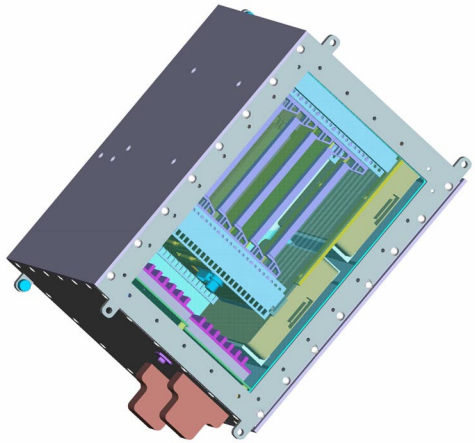
Common Image Processing and Storage Unit (IPSU)

Function

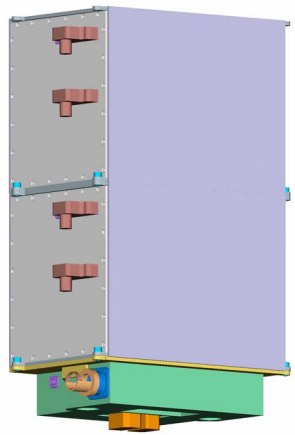
- Store image data received from an imaging module
- Perform automated real-time analysis of images
- Provide control signals to the image acquisition diagnostic control modules
- Provide control signals to the illumination diagnostic control modules
- Provide on-orbit image processing and data reduction to support near real-time (data reduction to begin within one hour after the data is acquired assuming a communications link is available), interactive (e.g., PI to FCF) evaluation of experiment data for the purpose of adjusting experiment protocol



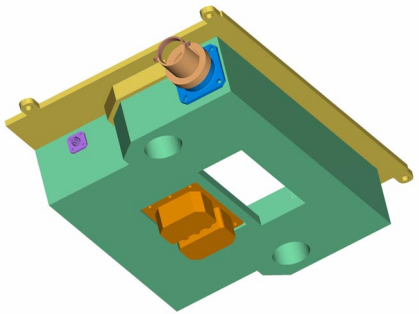
Common IPSU Packaging Concept



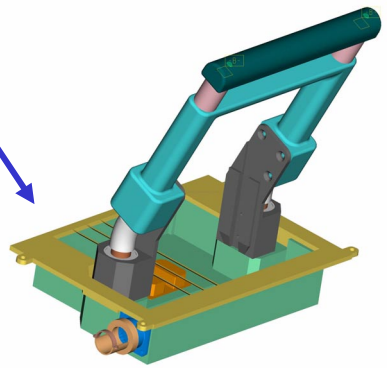
Single IPSU



Two IPSU Stack for CIR



Adapter Plate for CIR



Common IPSU

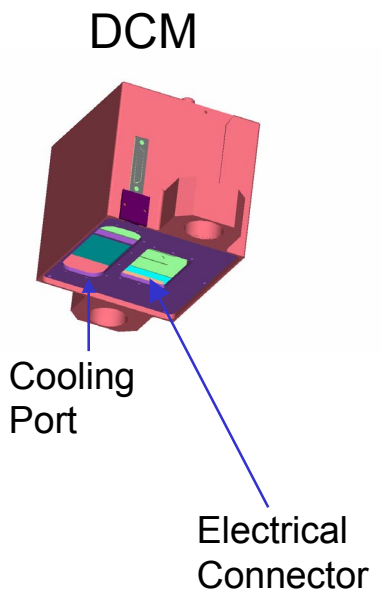
Communication interfaces

- Ethernet for command and control from IOP, downlink of image files
- CAN for command and control of camera lenses, translation stage, and gimballed mirror via CAN controller
- CAN for reporting health and status, including temperatures and voltages, via a CAN node
- Fiber video input to provide input to the Serial Data Link (SDL) board
- Analog video output from scan converter that converts digitally acquired data to an RS-170A signal
- Sync bus for synchronizing illumination sources, cameras, and IPSUs

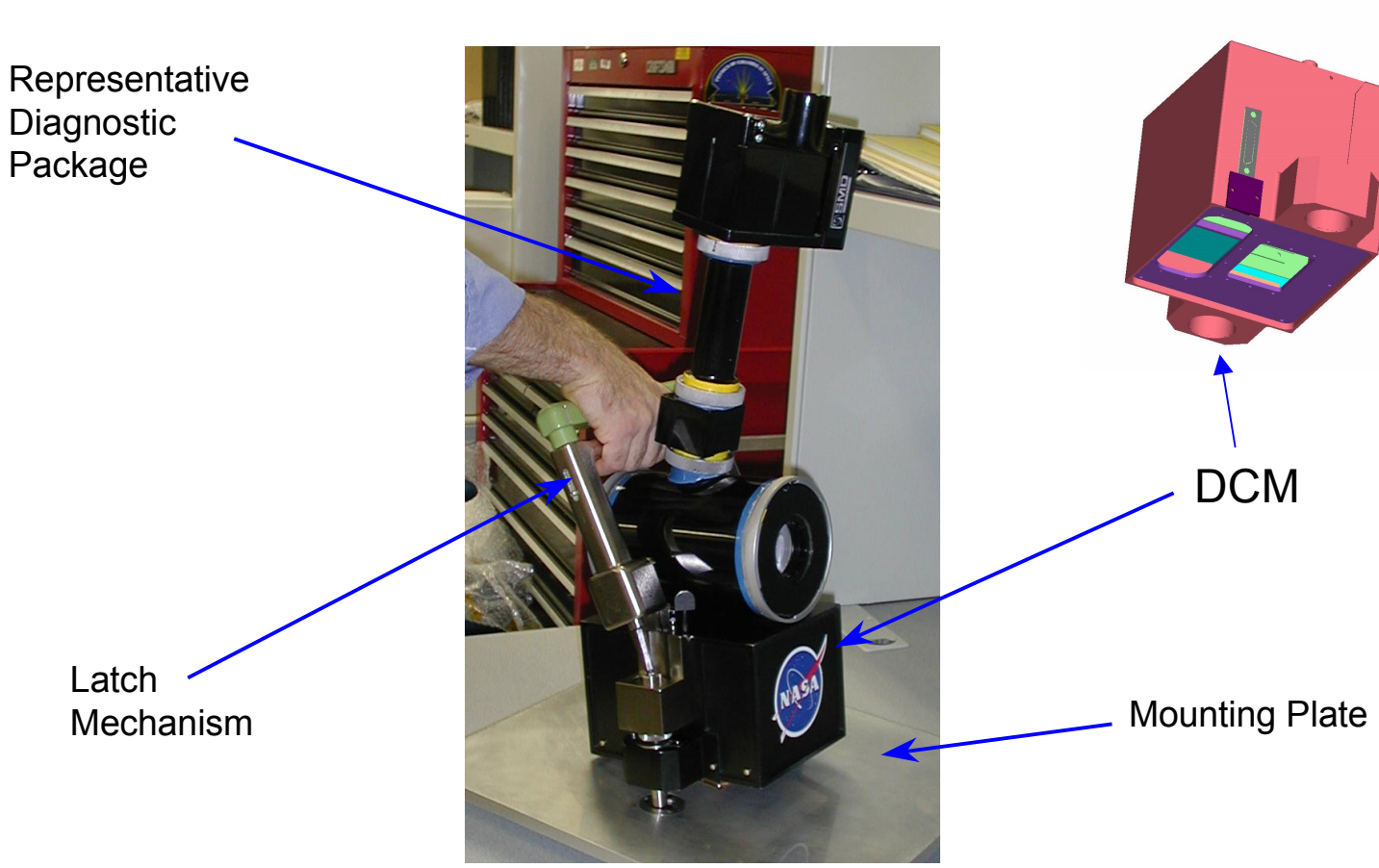
Diagnostics Control Module (DCM)

Function

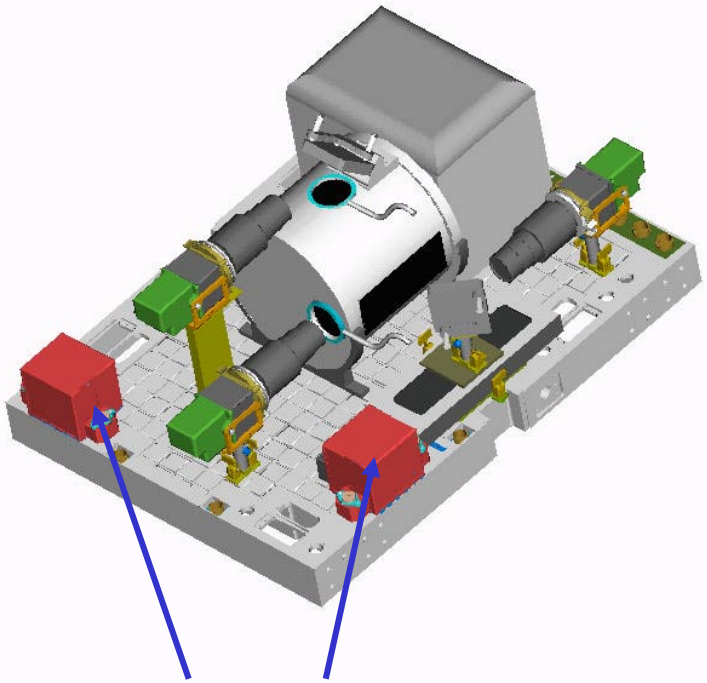
- Attaches to FCF Optical Benches and makes blind electrical and cooling connections
- Acts as the interface module for FIR Image Acquisition Modules (IAM) and motorized subsystems
- Acts as the interface module for CIR Diagnostic Packages
- Provides power conditioning and distribution
- Provides stress free attachment for optical assemblies via Kinematic interface
- Provides specific interfaces for:
  - Controls
  - Health status and reporting
  - Location ID
  - Data
  - Cooling
  - Diagnostics Alignment in CIR



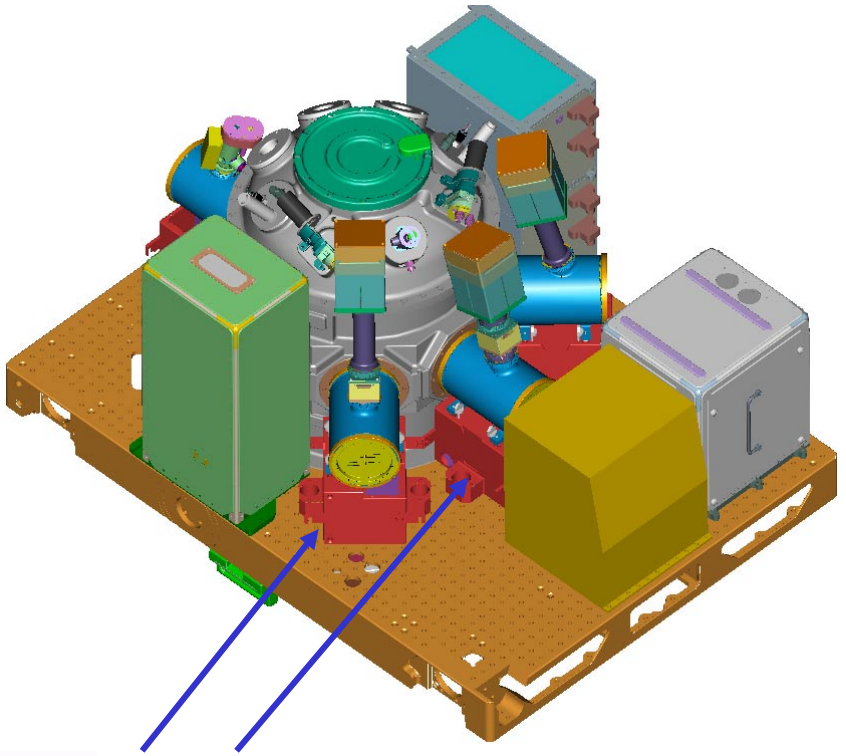
Diagnostics Control Module (DCM) and Latch



Typical Diagnostics Control Module (DCM) Utilization



Experiment f15b



Experiment c7

Diagnostics Control Module (DCM) Testing

Electromagnetic Interference (EMI)

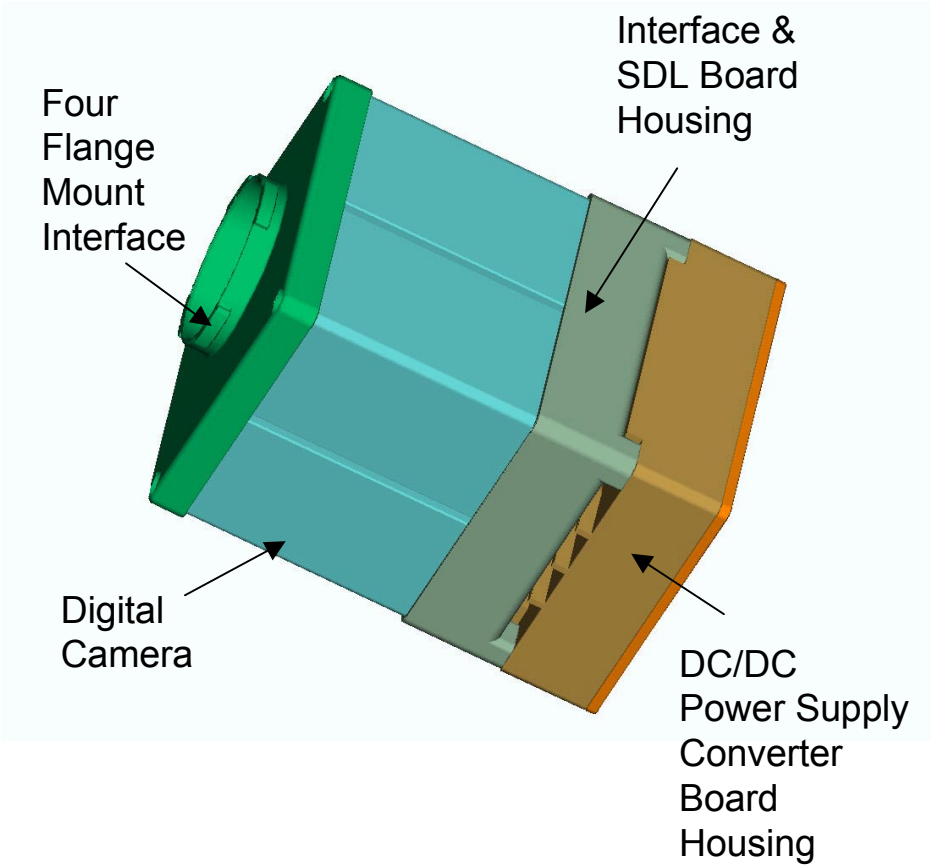
- A complete set of conducted/radiated emissions and conducted/radiated susceptibility tests were performed on a development DCM unit per FCF-PLN-0027 with no problems identified

Image Acquisition Module (IAM)

Function

- Provides a means of collecting the image provided by the package optical system and converts that image into a format that can be transferred, via optical fiber, to an Image Processing and Storage Unit (IPSU)
- Integrates Camera with its Power Supply and Serial Data Link (SDL)
- Provides Four-Flange Mount to interface with other modules

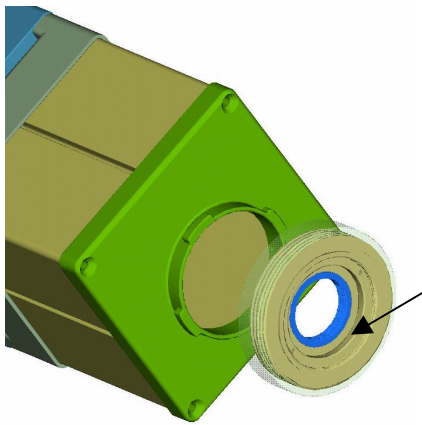
IAM (High Resolution Camera)

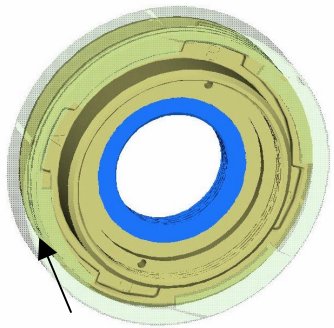


- Digital CCD Camera collects the image provided to it by the optical system, and converts the incoming photons to electrons. The Camera's internal electronics read the CCD array at a programmable framing rate and output a digital signal sent out on parallel data lines.
- Frame Rates: camera can bin data when higher frame rates are required.
- Bit Depth: 12 bit depth can be selected by binning the high frame rate camera; available without binning with the 10 MHz camera.
- Image Output: digital signal out on high data rate optical.
- Integral Power Supply: provides improved output stability and reduced background noise.

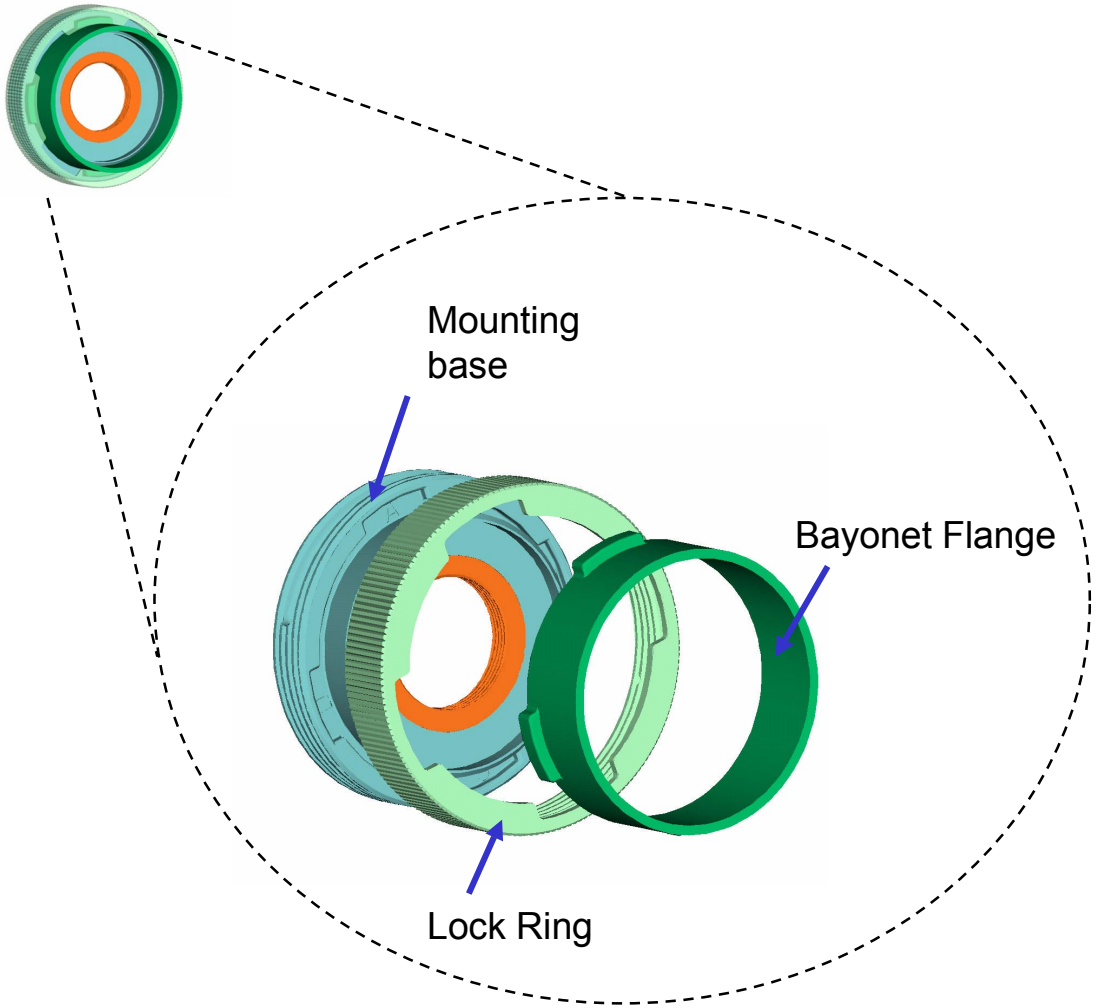
IAM Four Flange Mount Interface

- The Four Flange Mount Interface kit will include a Flange to C-Mount Adapter.
- This adaptor allows the FCF provided cameras to interface with standard C-mount lenses.





Flange to
C-Mount Adapter



IAM Testing

Thermal Test

- Objectives
  - Determine if a Thermoelectric Cooler (TEC) should be added to the Silicon Mountain Design (SMD) Camera
  - Investigate the Dark Current Generation under typical CIR and FIR operating environments
  - Investigate time to reach thermal equilibrium
  - Determine if it was possible to correct for dark current generation
- Test Setup
  - Two SMD 1M60-20 cameras (one modified with a TEC and one unmodified) were tested in the thermal chamber at the NASA Glenn Research Center

Documented in FCF-TRT-0096: Silicon Mountain Design CCD Camera Dark Current Generation Test Report

IAM Testing

Thermal Test – Continued

- Results
  - The addition of the Thermoelectric Cooler (TEC) resulted in only a 0.366% improvement in dynamic range at 30 fps over a camera without a TEC.
  - At 30 fps, the dark current was 75.3 gray levels in the CIR and 74.2 in the FIR.
  - Thermal steady state was reached in approximately 12-15 minutes.
  - A trendline predicting dark current generation as a function of heat sink temperature was obtained for the camera without a TEC. A trendline could not be determined for the TEC-modified camera.
- Recommendation
  - It is recommended that the SMD 1M60 cameras not be modified with a Thermoelectric Cooler (TEC). The marginal improvement of dark current generation (0.366%) does not outweigh the reduction of precision, lack of predictability, increase in complexity, and increase in power and weight.
- Electromagnetic Interference (EMI) Test
  - SMD camera with custom power supplies passed emission tests